VEGETATION ALLIANCES AND ASSOCIATIONS OF THE WHISKEYTOWN NATIONAL RECREATION AREA

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ABSTRACT

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This project employed a representative sampling approach to develop a hierarchical classification of forest alliances and associations on the 172 km^2 Whiskeytown National Recreation Area in Shasta County, California. Twenty alliances, thirty-nine associations, and ten "types" were found in the park. The positions of associations and vegetation polygons (sampling units) relative to each other along gradients of environmental variation were analyzed, and elevation was found to be the single most influential such gradient, followed by steepness of slope and moisture availability. The high number of alliances and associations found at Whiskeytown supports previous conclusions about the Klamath Region's importance as a "center" of plant diversity for the American West Coast. Furthermore, Whiskeytown's vegetation complexity is even more complex than that of most of the rest of the Klamath Region. This points to the complex nature of disturbance dynamics in the area.

A number of interesting and unusual vegetation types were found in the course of generating the classification. These types, which are indicative of Whiskeytown's location at the juncture of several physiographic and floristic provinces (and subsequent diversity), are described and detailed in this classification, as well as a few types that are known to occur in the park but for various reasons did not come under the scope of the classification.

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INTRODUCTION

Whiskeytown National Recreation Area

Whiskeytown National Recreation Area (WNRA) is a 17,200-ha park that lies at the juncture of several of northern California's physiographic regions. Here the Klamath Mountains, which are part of the most floristically diverse ecological unit in the western United States and of which WNRA forms the southeastern terminus, face the beginnings of the Pacific Northwest's Cascade Range in one direction, the northern end of California's Great Central Valley in another, and the inner slopes of the Coast Ranges in yet another. This transitional location and subsequent variation in terrain and geologic composition make WNRA's vegetation complex one of the most diverse and interesting floras in the state. At least sixteen threatened, endangered, or sensitive species are found at WNRA (National Park Service 2000). Despite this diversity and ongoing efforts to inventory native plant species in the park, WNRA's vegetation has never been hierarchically classified or mapped.

Adding to this complexity is WNRA's long and varied history of disturbance. WNRA is located at one of the most historically active gold-mining areas in California (Hotherm and others 2002); it also encompasses several homestead sites of archeological significance where vegetation was cleared and is now recovering from grazing pressure. Perhaps the most important historical disturbance, however, is fire. Along with recreational use, fire is an important ongoing potential disturbance to park vegetation; it produces a variety of effects on vegetation depending on fire severity, extent, and location. The Klamath Region in general has historically experienced both high fire frequency and high variation in fire severity (Taylor and Skinner 1998). Many plant species in the park have evolved fire-tolerant or fire-dependent mechanisms (for example, the burls at the base of chamise, *Adenostoma fasciculatum*, which sprout after fire, or the serotinous cones of knobcone pine, *Pinus attenuata*) and so depend on fires for regeneration; however, in a situation familiar to most of the American West, fire suppression in some areas of the park may have led to a build-up of young trees and shrubby vegetation that encourages high-severity fires (National Park Service 2001) with the potential to destroy soil seedbanks, kill mycorrhizal fungi, contribute to soil erosion, and make park areas vulnerable to non-native species invasions (Agee 1993).

Vegetation Classification

These disturbances have produced a mosaic of vegetation types and recovery regimes across WNRA. Vegetation classification provides a way of distinguishing between the pieces of this mosaic and arranging them into a hierarchy that enables a clearer understanding of their relationships with each other. To some extent, classification is a basic human response to complex systems such as natural ecosystems (McCune and others 2002) and has intrinsic appeal. Usually, however, classification is used not as an end in itself, but as part of a strategy to summarize information about large land-management units as a tool to aid the decisions that land managers must make about natural resource restoration, allocation, and use. Goodall (1978) points out that we classify because by knowing the classes in which plant communities have been placed, we want to be able to predict certain attributes about those communities and their abiotic environments. Vegetation classification, being a human construct created to be helpful to humans for land management, biodiversity conservation, or other reasons, inevitably has an element of the arbitrary about it (Sawyer and Keeler-Wolf 1995). It cannot help but lean somewhat more toward the "Clementsian" view of plant communities as discrete communities consistent in appearance and composition (Clements 1916; Clements 1920) than toward the "Gleasonian" view of vegetation as a continuum of plant species that respond individually and idiosyncratically to variations in environmental variables (Gleason 1939).

More importantly, however, vegetation classification serves as the foundation for a number of other basic vegetation management applications. Prominent in plant ecology research is the technique of linking the vegetation classification of an area to the environmental variables present in that area by the techniques of multivariate biometry involved in ordination and gradient analysis, as in Mahony (1999) and Riegel (1982). Such an analysis provides valuable data to natural resource managers who are seeking to understand trends in vegetation distribution across spatial areas and how various management actions will affect that distribution.

Vegetation mapping is another valuable resource management application that requires classification. The present study has its origins in such an application; this classification will serve as the first step in a standardized process, using consistent taxonomic and ecological units of plant species and communities, of mapping WNRA's vegetation and linking it to a nation-wide effort to map the vegetation of lands in the national park system. A knowledge of the vegetation classification of an area is very useful to a photo interpreter as he or she delimits areas of continuous vegetation (polygons) on the photo or satellite image for transfer to the final map (Environmental Systems Research Institute and Nature Conservancy 1994).

Classification is also important because it can serve as a record of vegetation types in order to display the biological diversity of a single land-management unit for conservation purposes and biodiversity protection (Environmental Systems Research Institute and Nature Conservancy 1994). This applies not only to vascular plant diversity, but also to other kinds: the occurrences of many kinds of animals, fungi, bryophytes, and lichens, for example, are strongly correlated with certain kinds of vascular plant habitats. A vegetation classification for such purposes should be hierarchical, that is, organized so as to catch more than one level of information about the biological diversity of an area.

This study employs the alliance/association system of classification units developed by the Ecological Society of America as part of the U.S. National Vegetation Classification effort. One can think of these units as "supertaxa" that obtain their status in vegetation classifications not from any of the numerous criteria (cladistic, morphological, life-form, etc.) used in classifying plants into species, genera, families, and so forth, but from their co-occurrence spatially and temporally in associations. An association, the basic unit of classification, is defined as "a recurring plant community with a characteristic range in species composition, specific diagnostic species, and a defined range in habitat conditions and physiognomy or structure" (Ecological Society of

America 2002). Association names typically consist of one or more names of diagnostic (constant) species of each stratum of the vegetation. These names characterize the vegetation unit for identification. An alliance is defined as "a grouping of associations with a characteristic physiognomy, and sharing one or more diagnostic species, which, as a rule, are found in the uppermost or dominant stratum of the vegetation" (Ecological Society of America 2002). Again, alliances take their names from the diagnostic species, although, as the definition mentions, only those species in the uppermost stratum of the vegetation are used for an alliance name. Since classification is a subjective human activity, alliances and associations can be variable in appearance across the landscape.

Hierarchical classifications enable use by land managers with a variety of different objectives. A certain area of forest characterized by dominance in the canopy of *Pseudotsuga menziesii* and *Lithocarpus densiflorus*, for example, may be mapped at the relatively coarse scales sufficient for fire- and timber-management purposes as a *Pseudotsuga menziesii – Lithocarpus densiflorus* forest alliance. However, the understories of some such forests may consistently contain dense growths of *Rubus ursinus* that are valuable as cover for certain birds or mammals, while the understories of others have no *Rubus ursinus.* In this case, a classification to the association level may be helpful for wildlife biology applications.

Classifications in the Klamath Mountains Region

Relatively few plant classification efforts have taken place in the Klamath Mountains, and those that have taken place have usually been undertaken in widely scattered areas throughout this large region, many on parent materials different from those present in WNRA. Whittaker (1960) explored transects from low-elevation forests near the northern California and southern Oregon coast eastward to higher-elevation forests in southern Oregon on three major parent material substrates (serpentine, gabbro, and diorite), concluding that four major “formation-series” appear in the area: Coast Forest, Mixed Evergreen Forest, Oak Woodland, and Valley Grassland. Mize (1973) described lower elevation forests on granitic parent material in western Siskiyou County and identified four vegetation types. Sawyer and Thornburgh’s (1974) study identified sixteen vegetation associations on granodiorite parent materials. Taylor and Teare (1979) recognized five alliances and eight associations in the South Fork Trinity River watershed in the southern Klamath Mountains. Palmer (1979), studying diorite substrates in the Bear Lakes area of the Scott Mountains in the east-central Klamath Mountains, discerned twelve vegetation types with three phases, which he further elucidated using phyiognomic nomenclature. Simpson (1980) described four series and twelve vegetation types occuring on ultramafic soils in the Siskiyou Mountains (western Klamath Mountains).

Sawyer and Thornburgh (1977) divide the Klamath area into western and eastern subregions and mention the vast differences between the vegetation of the two, such that a knowledge of the vegetation of one subregion is not a reliable guide to the vegetation of the other. Moreover, even within the eastern subregion, where WNRA is located, differences in topography and parent materials make generalizing between studies difficult; few of the vegetation associations mentioned in the above studies resemble those at WNRA. A major study that is applicable is the soil-vegetation survey of Mallory and others (1973), who mapped 178 phases of soils as well as 29 miscellaneous land types within the French Gulch 15' Quadrangle, which ecompasses the four 7.5' Quadrangles (French Gulch, Shasta Bally, Igo, and Whiskeytown) that contain WNRA. They also mapped 17 soil-vegetation associations that they classified into three basic types: conifer forest, chaparral, and woodland-grass. Another study containing some associations similar to ones found at WNRA is that of Stuart and others (1996) in Castle Crags State Park in Shasta County, which resembles WNRA in being located in the transitional zone between floristic provinces (in this case, the Klamath Mountains and the Cascades). The study described eight series encompassing fifteen associations.

Purpose

No complete description and classification of WNRA's many kinds of vegetation types has yet been undertaken. Such a description and classification would facilitate the decisions necessary to efforts to appropriately manage disturbance regimes (such as fire and native species invasion) and to monitor populations of rare plant and animal species across the park. Of these management concerns, fire is the chief. High-severity fires have the potential to spread to urban and suburban areas in and near the town of Shasta (~0.8 km from WNRA) and the large town of Redding (~5 km). With this in mind, park staff have initiated an alliance-level mapping project of WNRA's vegetation. This classification is the first step in this project; it will serve as an important data layer for the final map of vegetation alliances that will provide critical information for fire management applications.

However, a classification of WNRA's vegetation is of more general interest as well, since it fills in a gap in knowledge about the Klamath Mountains as a whole. It illustrates some of the ways in which Klamath Mountain floristic elements have historically interacted with elements from the younger physiographic provinces (Coast and Cascade Ranges, Great Central Valley and even Great Basin) to the west, south, and east. It provides an interesting opportunity to assess the relative contributions of several environmental variables, such as diverse topography, parent materials, and microclimatic conditions, to the varying appearance of vegetation across the park. Finally, it provides an interesting snapshot of the recovery from disturbance of, or the effects of continuing disturbance on, several kinds of diverse vegetation types in an area of high environmental variability and heavy human recreational use.

STUDY AREA

Location

WNRA lies in Shasta County, California, just east of the Trinity/Shasta County line, along which the park's western boundary runs. The park extends from 40° 30'N to 40° 40'N and from 122° 30'W to 122° 42'W. The towns of Shasta and Redding lie to the east of the park, the Shasta-Trinity National Forest to the north, the communities of Ono and Igo to the south, and Bully Choop Peak and Buckhorn Summit to the west. State Route 299 bisects the northern half of WNRA, running from east to west above Whiskeytown Reservoir, a 1295-ha lake formed by a dam on Clear Creek finished in 1963. Only a few major roads, intersecting Highway 299, run through the park area. These include County Line Road on the western boundary; Crystal Creek Road, which parallels the drainage of the same name on the west end of the reservoir, climbs in elevation, and forks to run toward both Shasta Bally and Bully Choop Peak to the west; J.F Kennedy Memorial Drive along the south shore of the reservoir; Paige Bar and Mule Town Roads, which run from the southeast corner of the reservoir south out of the park; and Shasta Bally Road, which climbs to the mountain's summit. The area is covered by four USGS 7.5' series topographic quadrangles: Igo, Whiskeytown, Shasta Bally, and French Gulch. The complete area of the park is 172 km^2. Figure 1 shows WNRA's location and features.

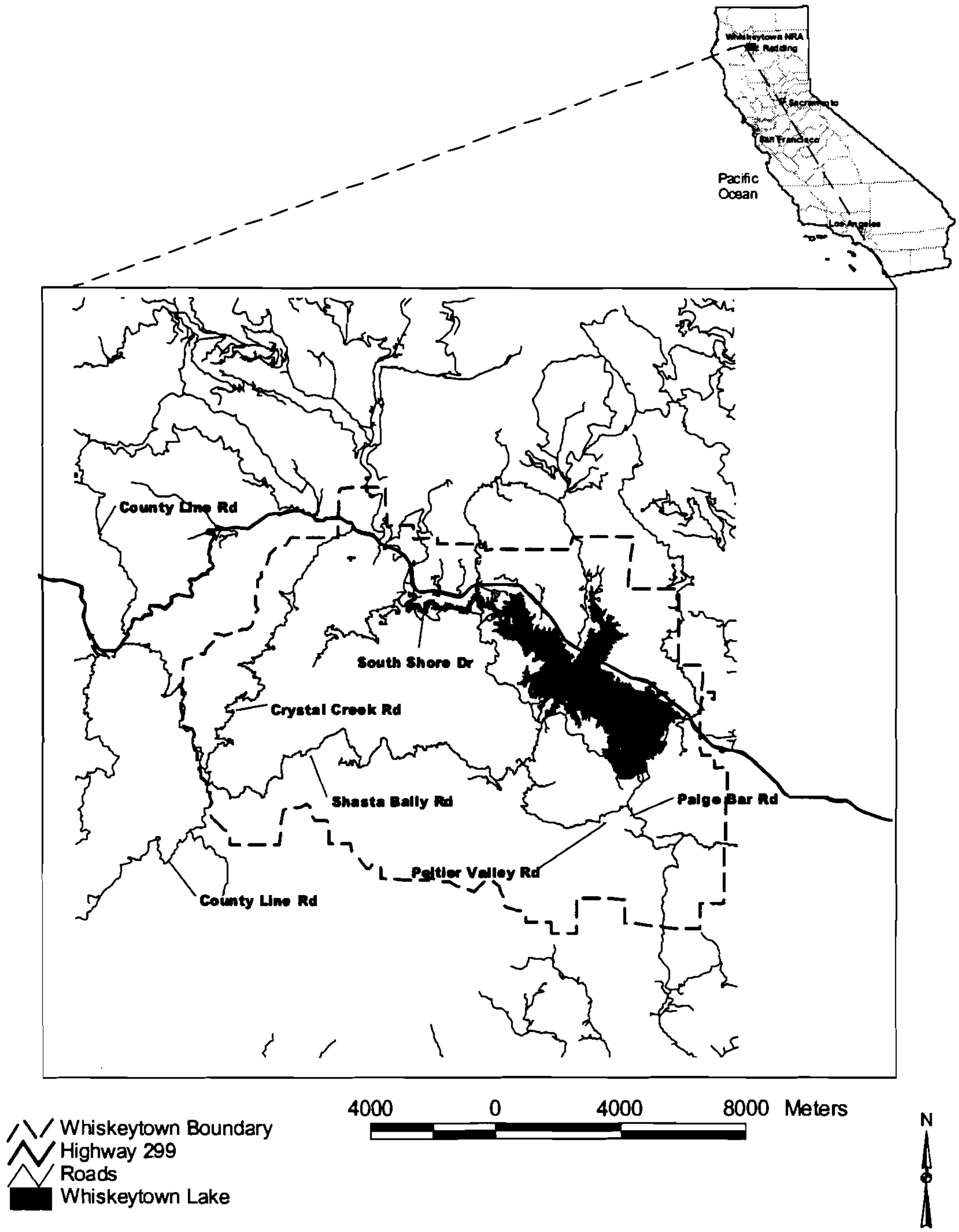

Figure 1. Location and features of Whiskeytown National Recreation Area (California Mapping Coordinating Committee 2003; National Park Service 2003).

Topography

One of the most striking environmental features of WNRA is its topographic relief. This is epitomized by the rise of Shasta Bally, which climbs from 390 m at the base to over 1860 m in a horizontal distance of slightly more than 4 km (an average slope of 37%). Numerous streams incise the park, producing ridges that trend in several directions and produce gradients in excess of 75%. Of these streams, only Clear Creek features a very broad alluvial floodplain. Elevations across the park range from 244 m near Lower Clear Creek in the southeast corner of the park to the top of Shasta Bally at 1860 m.

Geology

WNRA lies at the end of the Eastern Klamath belt, which is composed of 12,000-15,000-m thick columns of rock originating in periods from the Ordovician (500 million years before present) to the Jurassic (160 million years before present). To the west, this belt abuts the late-Jurassic ultramafic rocks of the central Klamath Mountains; to the east it grades into the northern sector of the Great Central Valley (Irwin 1974). Along Highway 299 north of Whiskeytown Lake, the Balaklala Metarhyolite (Devonian), Copley Greenstone (Devonian), and Bragdon Formation shale and mudstone (Mississippian) are exposed, as is the faulted contact between the last two formations (Snoke 1974). Toward the western boundaries of the park near Buckhorn Summit lies a group of granitic plutons, emplaced within the late Jurassic period, that separate the sedimentary rocks of the Eastern Klamath belt from the ultramafics of the central Klamaths. Shasta Bally is the largest such pluton; it is composed of biotite-hornblende granodiorite and quartz diorite and is shallowly eroded (Irwin 1974; Snoke 1974). The batholith is bordered by a band of gneiss and amphibolite produced by contact metamorphism of surrounding rocks during the emplacement of the granite (Mallory et al. 1973). The Mule Mountain light-colored granite, south of the Balaklala Metarhyolite, represents an intrusion accompanied by metamorphism of the Balaklala and Copley rocks (Kinkel et al. 1956).

Soils

The United States Soil Conservation Service has mapped a wide diversity of soil associations within WNRA (United States Soil Conservation Service 1967). North of Highway 299, soils are primarily Mariposa-Maymen, Auburn-Brandy, and Josephine-Sites associations; south of the highway they primarily fall into the Chawanakee-Corbett, Goulding, Auburn-Brandy, and Josephine-Sites associations. These soils reflect the two most prevalent parent materials in the park, sedimentary rocks and granite. Most soils are found on steep slopes and are highly erosive. General characteristics of the soil series that make up these associations are listed in Table 1.

Table 1. General Characteristics of Soil Series (from USSCS 1967).

Soil Series	**Mariposa**	**Maymen**	**Auburn**	**Brandy**	**Josephine**
Depth Range (cm)	50-76	25-50	41-76	50-123	91-152
Color of surface/subsoil	brown/light brown	brown/brown	yellowish red/yellowish red	brown/red	reddish-brown/light reddish-brown
Texture of surface/subsoil	gravelly loam/gravelly heavy loam	gravelly loam/gravelly loam	loam/loam	gravelly loam/gravelly loam	loam/clay loam
Reaction of surface/subsoil	moderately acid/strongly acid	moderately acid/strongly acid	slightly acid/slightly acid	moderately acid/moderately acid	slightly acid/moderately acid
Parent material	shale or slate	shale, conglomerate, schist, sandstone	greenstone	greenstone	shale, conglomerate, schist, sandstone
Relief/position	very steep	very steep	steep	steep	steep to very steep
Permeability	moderate	moderate	moderately slow	moderately slow	moderately slow
Drainage	good	somewhat excessive	good	good	good
Erosion hazard	very high	very high	high	high	very high
Fertility	low	very low	moderate	moderate	moderate
Runoff	medium	rapid	rapid	very rapid	rapid

Table 1 General Characteristics of Soil Series (from USSCS 1967) (continued).

Soil Series	**Sites**	**Chawanakee**	**Corbett**	**Goulding**
Depth Range (cm)	76-152	76-152	61-152	30-61
Color of surface/subsoil	brown/red	grayish-brown/pale brown	grayish-brown/pale brown	brown/brown
Texture of surface/subsoil	loam/clay	sandy loam/weathered rock	coarse sand/coarse sand	loam/loam
Reaction of surface/subsoil	slightly acid/slightly acid	moderately acid/moderately acid	moderately acid/moderately acid	slightly acid/slightly acid
Parent material	sandstone or conglomerate	granitic rocks	granitic rocks	greenstone
Relief/position	steep to very steep	very steep	very steep	very steep
Permeability	slow	moderately rapid	rapid	moderate
Drainage	good	excessive	excessive	good
Erosion hazard	high	high	very high	very high
Fertility	moderate	moderate to low	moderate	very low
Runoff	medium	medium	medium	rapid

Climate

California east of the North Coast Ranges retains the Mediterranean climate of the coast in terms of precipitation (dry summers and wetter winters), but temperature variance from winter to summer increases with distance from the ocean. WNRA lies at the juncture of several of California's physiographic provinces, including the Klamath Mountains, the Great Central Valley, the Inner North Coast Ranges, and the Cascade Range (Hickman 1993). Elford and McDonough's (1965) warnings against generalizing about weather patterns in Siskiyou County hold true for Shasta and Trinity Counties as well: the region's complex topography dictates extreme fluctuation in weather patterns over short linear distances. Since Trinity and Shasta Counties are located where the Pacific Ocean's influence on climate begins to weaken, varying amounts of precipitation, wind, and relative humidity interact with topography to produce a mixture of microclimatic effects.

On average, WNRA is one of the wetter areas of the Klamath Mountains area: the Whiskeytown Reservoir weather station recorded a thirty-year average rainfall of 1500 mm (WorldClimate 2002), as compared to 308 mm at Montague and 1173 mm at McCloud (Felton 1965). Almost all this rain falls between November and March. Snowfall is extremely light. Average annual snowfall is only 97 mm, with the majority of that falling during January (Western Regional Climate Center 2001).

Like most of the surrounding area, WNRA experiences hot summers, which are sometimes exacerbated by warm air escaping from the Great Basin and flowing westward through California (Western Regional Climate Center 2001), and moderately cool winters. Average maximum temperatures at Whiskeytown Reservoir range from 11.9° C in December to 35.1° C in July; average minimum temperatures range from 1.8° C in January to 17.4° in July (WorldClimate 2002). Temperatures vary widely between daytime and nighttime, with the average diurnal temperature range being about 15-20° C (Felton 1965). Summer temperatures above 38° C are fairly common.

Most lightning strikes throughout the Klamath Mountains occur in July and August (Automated Lightning Detection System cited in Frost & Sweeney 2000), when moisture in live fuels has had a number of months to evaporate and volatile oils in flammable shrubs are concentrated. Fires that result from these strikes can typically burn in steep or remote topographic locations, where suppression is difficult, for weeks or months.

Vegetation

An extremely diverse set of plant species grows in and around WNRA thanks to the park's extreme variation in aspect, elevation, and topography. The most noticeable environmental gradient appearing to control vegetation distribution in the park is the elevational gradient. At the elevation of the reservoir, the vegetation is dominated by *Arctostaphylos viscida, Heteromeles arbutifolia, Toxicodendron diversilobum, Quercus kelloggii, Quercus chrysolepis,* and scattered conifers such as *Pinus sabiniana* and *Pinus attenuata.* Southern slopes, especially slopes along the north side of State Route 299, are often only shrublands; toward the top of these slopes, outside the boundaries of the park, *Arctostaphylos viscida* chaparral begins to grade into *Adenostoma fasciculatum* chaparral.

As one leaves lower elevations and begins to climb the flanks of Shasta Bally, the vegetation pattern changes noticeably. *Pseudotsuga menziesii, Lithocarpus densiflorus* var. *densiflorus, Pinus ponderosa,* and *Pinus lambertiana* become more important components of the canopy, and the ubiquitous shrubs of the lower elevations begin to disappear. At around 600 m *Arctostaphylos patula* begins to replace *Arctostaphylos viscida*, and at around 900m *Abies concolor* and *Ceanothus prostratus* become noticeable components of the tree and shrub layers. As one reaches the upper limits of the park's elevation (1500 m and above) on the upper slopes of Shasta Bally, *Lithocarpus densiflorus* var. *echinoides* becomes the dominant shrub, sometimes forming pure shrublands on all topographic aspects but more often occurring with *Pinus ponderosa, Pinus lambertiana, Pseudotsuga menziesii,* and *Abies concolor* in woodlands with extremely widely scattered trees. *Abies magnifica* also appears at the highest elevations. Other shrubs that are important above the 1500-m level are *Arctostaphylos patula, Chrysolepis sempervirens,* and *Arctostaphylos nevadensis.*

Riparian vegetation across the park varies widely and is markedly species-rich. It is generally dominated by *Alnus rhombifolia*, although *Pseudotsuga menziesii, Quercus chrysolepis, Fraxinus latifolia,* and *Lithocarpus densiflorus* var. *densiflorus* are also common. Several species of *Salix* are usually present. *Rubus* spp. and *Vitis californica* are common shrub species. Common herbaceous plants include *Carex nudata, Darmera peltata, Aralia californica,* and, at higher elevations, *Leucothoe davisiae.*

MATERIALS AND METHODS

Selection of Sample Stratification Method

The USGS/NPS vegetation mapping program (Environmental Systems Research Institute and Nature Conservancy 1994a and 1994b) specifies that parks falling into the "Large" category (100-2500 km^2) employ the gradsect method of sample stratification described in Gillison and Brewer (1985) and Austin and Heyligers (1989). This sampling method stratifies the placement of plots across a spectrum of environmental gradients within the park while ensuring that plots are accessible and cost-effective. However, it was determined that for this project the use of representative polygon stratified sampling, wherein vegetation is classified into similar polygons and plots placed in every vegetation type thus identified (the strategy that the USGS/NPS standards recommend for "Medium parks"), was preferable for several reasons. First, the relative paucity of roads in some areas of the park where significant vegetation associations and alliances exist would make it difficult for a sampling strategy to meet the "near-road" criteria of gradsect plots. Second, the park, at approximately 172 km^2, is at the small end of the "Large park" category defined in the USGS/NPS standards, which means that regional environmental gradients are not likely to be the driving factors behind the vegetation pattern in the park. Whittaker (1960) argued that the most significant such gradient throughout the Klamath Mountains is parent material. WNRA is small enough that the scope of this gradient's influence in the park cannot be termed "regional." After parent material, the next most significant environmental variables pointed to by Whittaker were local topography and elevation; these seemed much more likely to be the most significant environmental gradient in the park. Third, much of the park and buffer area is recovering from disturbance, suggesting that the nature of the disturbance may significantly influence vegetation and may mask the influence of environmental gradients to some extent. Fourth, since the park almost falls into the "Medium" category, it was determined that greater sampling accuracy could be achieved with the use of representative polygons, which are likely to capture more of the variation across the park than the gradsect approach.

Vegetation Classification Approaches

The USGS/NPS vegetation sampling standards state that for medium and larger parks, at least ten plots will be sampled per vegetation type. The standards deliberately use the vague term "vegetation type" because they offer each park latitude to employ any one of several methods of describing vegetation composition and distribution. Chief among these methods are the "physiognomic" approach and the "floristic" approach. The physiognomic approach classifies vegetation by its outward appearance; this approach defines a number of categories and then orders the vegetation types across the park into these categories (a "top-down" approach"). Using the physiognomic approach, some example vegetation types might be "subalpine meadow," "low-elevation mixed-evergreen forest," or "foothill deciduous woodland." The floristic method, in contrast, is a "bottom-up" approach that inventories the species present in sample plots and generates associations and alliances from those inventories.

The image-driven unsupervised classification of the Whiskeytown Unit for stratification purposes used spectral signature as a surrogate for actual observed vegetation types, as described in Keeler-Wolf and Vaghti (2000). The 58 initial spectral classes described below, plus riparian "classes," compose this study's equivalent of the "vegetation types" mentioned in the USGS/NPS standards. As Keeler-Wolf and Vaghti (2000) mention, it is important to remember that the final supervised classification product of this study should differ significantly from the initial, unsupervised classification. In effect, the study employed a semi-physiognomic classification to stratify the study area for sampling, but the final product is a floristic classification.

It is important to note that this sampling design is not a true stratified random sampling design. In other words, the spatial extent of any vegetation type in the study is not directly correlated with the number of polygons that were sampled for that type.

Number of Plots

Upland

Initially, the Whiskeytown Unit was stratified using physiographic criteria derived from USGS digital elevation models. The Whiskeytown Unit was divided into the following three elevational classes, all of equal area within the park: 211-499 meters; 500-814 meters; and 815-1899 meters. The park was also divided into two broad aspect classes, selected according to ecological significance: the northerly (azimuth 315-135 degrees) and southerly (azimuth 136-314 degrees) classes. Since there were three elevational classes and two aspect classes, six zones were possible across the park.

Each of these six physiographic zones underwent an unsupervised classification of a LANDSAT Enhanced Thematic Mapper image using ERDAS Imagine (v. 8.4) software. The classified maps were based on bands 1, 2, 3, 4, 5, 7, and band 8 was spatially merged in order to achieve a resolution of 15 m x 15 m. Each physiographic zone was classified into 30 vegetation classes. The six unsupervised classifications (180 classes total) were then analyzed using divergence criteria to test for statistically significant differences between spectral classes. Those classes found to be equal to or below the transform divergence statistic of 1200 were combined into larger unified classes. The 58 unified classes were combined (classified) in the raster map and exported into an ARCINFO file in order to generate polygons. After vectorization (converting raster maps to vector GIS coverages) the three largest polygons of each class that were near roads were selected for sampling.

As mentioned above, the 58 spectral classes are the "vegetation types" to which the USGS/NPS standards refer, and at least nine relevés (see "Plot Shape and Size," below) were placed within each spectral class. Therefore, the unsupervised classification for this project having determined 58 possible spectral classes for the analysis, approximately 522 plots (58 classes x 3 polygons/class x 3 relevés/polygon) were required for the upland areas of the project. A single vegetation class contained anywhere from a few to dozens of polygons larger than 0.5 ha scattered throughout the study area. Very few spectral classes, though, contained fewer than 3 polygons.

Riparian

Possible riparian associations represent important vegetation types that elude the image-driven stratification process because of the thin shape of riparian patches and because such patches do not necessarily produce unique, separable spectral signatures. Instead of using an image-driven stratification process for these types, USGS 7.5' topographic quadrangles were inspected in order to identify riparian sampling sites. The goal was to select between 25 and 30 riparian sampling sites. After inspecting creeks and gulches close to roads within the study area, 28 sampling sites were chosen. Two plots were established per sampling site for a total of 56 riparian plots.

The total number of plots was 578: 522 upland and 56 riparian plots.

Plot Shape and Size

This sampling effort employed circular plots in order to maximize the area sampled in proportion to the ease of plot layout (except in the case of vegetation types of unusual shape; see below). For tree-dominated vegetation types, crews laid out 0.05 hectare plots (12.6 m radius; 0.12 acre, 41.4-foot radius); for shrub- and herb-dominated vegetation types, they used 0.02 hectare plots (8.0 m radius; 0.05 acre, 26.2-foot radius). This project utilized a vegetation sampling technique known among plant sociologists as the relevé approach, developed by Josias Braun-Blanquet (1884-1980) in Europe as a method of time-effectively sampling vegetation over large areas of land. Instead of tallying intersections of plant species with transect lines through the terrain under study, the relevé approach, which the California Native Plant Society terms a "semiquantitative method," employs ocular estimates of plant cover over plots placed in vegetation taken to be representative of a particular type, where the plots are of fixed size but variable shape depending on the shape and extent of the vegetation along the terrain (California Native Plant Society 1998). For example, to sample vegetation along a riparian corridor, field crews might lay out a plot with a shape that is long and narrow relative to, say, a plot in a forested setting, which might be a more compact square or circle. Field crews had discretion as to plot shape in vegetation types of unusual shape, as long as the dimensions of each plot were kept constant (i.e., 0.05 ha for tree-dominated types and 0.02 ha for shrub- and herb-dominated types). The most important consideration was to ensure that the entire plot was representative of the vegetation type that the crew desired to sample.

Plot Location

Upland

The unsupervised classification resulted in over 1,200 polygons larger than 0.5 ha of the 58 spectral classes across the park. A buffer of 150 m on either side of the park's roads was established in ARCINFO in order to select easily accessed polygons. The three largest polygons of each class that intersected any part of the road buffers were then chosen. (Five classes that needed representation in the sampling scheme did not intersect the road buffers.) Field crews established three relevés per polygon for a total of 9 relevés per spectral class. The spectral classes and relevant location data for each upland polygon are contained in Appendix B.

Riparian

Sampling sites along creeks and gulches were marked on USGS 7.5' topographic quadrangles and then digitally located on available 12-bit, 1-m resolution DAIS (Digital Airborne Imagery System) imagery. Elevational diversity and proximity to roads were two important criteria for locating plots.

So that the plots maintained relevé attributes (be characteristic of representative riparian types—see "Plot Shape and Size," above), they were allowed to be of irregular shape, as long as they maintained the specified area coverages for plots (0.05 ha for tree-dominated types, 0.02 ha for shrub- and herb-dominated types). At each sampling site, one plot was located on each side of the stream. Appendix C contains the vegetation classes and relevant location data for riparian plots.

Data Collected within Each Plot

Crews collected the following categories of information: biological, environmental, location, and historical/disturbance. Biological information enabled (1) a species-driven classification of the vegetation into alliances and associations and (2) descriptions of each of these levels of vegetation communities that included information about those communities' horizontal and vertical structures. Environmental information helped to provide data for an analysis of the relationships that exist between environmental variables, such as elevation, slope, and aspect, and plant communities present in the plots. Location information enabled plots to be mapped and re-located on the map or in the field if necessary. Historical/disturbance information provided additional knowledge about how the plot's history and/or atypical features have influenced the vegetation present in that plot.

Biological Information

In order to provide information about the vertical structure of the vegetation on each plot, crews divided each plot into layers (Ground, Shrub, Tree) and measured the average height with a clinometer. The total percent cover of each stratum was estimated by eye. Tree seedlings were counted as part of the herbaceous stratum, and saplings as part of the shrub stratum. For the measurement of each stratum it was not necessary to record total percent cover by species.

Crews recorded each species present on the plot and percent cover of each species by ocular estimation. The percent cover of any one species could not exceed 100%, although the sum of the percent covers of all species could exceed 100%. Crews recorded the species and percent cover of trees, shrubs, or herbs that fell outside the plot but that provided cover within the plot. Any species whose canopy overlapped the plot boundaries was recorded irrespective whether the stem of the plant was in the plot.

For the recording of percent cover, crews used a modified Braun-Blanquet cover abundance scale, as shown in Table 2 below (adapted from California Native Plant Society 1998 and Mahony 1999).

Table 2. Cover abundance scale used in ocular estimates.

Cover Class	Cover Range (%)
1	0.001 – 0.01
2	0.01 – 0.1
3	0.1 – 1
4	1 – 5
5	5 - 15
6	15 – 25
7	25 – 50
8	50 – 75
9	75 - 100

Environmental Information

Crews recorded the following environmental information for each plot, using the methods specified below:

1. Location: UTM (GPS)
2. Elevation (GPS)
3. Topographic position/landform (from a standardized list)
4. Percent slope (clinometer)
5. Aspect class (compass)

In addition, the following two environmental variables were determined: first, an ARCINFO file containing the soil series and phases of Mallory and others (1973) was merged with the file containing vegetation polygon locations and queried to determine the soil type for each polygon. From these soil types, geologic parent materials were determined for each polygon. Second, a moisture equivalency index was adapted from Sawyer and Thornburgh (1974) and Mahony (1999) (Table 3) and calculated for each polygon. The index incorporates topographic position with aspect for each polygon to estimate soil water availability for the site; an index score of 1 represents saturated conditions, while a score of 15 indicates the least amount of available water.

Location Data

In addition to the environmental location mentioned above, crews labeled the field forms for each plot with a code that identified that plot's unique position. Crews also provided directions to the plot from familiar landmarks, using compass directions and

Table 3. Moisture equivalency index (adapted from Sawyer and Thornburgh 1974 and Mahony 1999).

Index Number	Topographic Position	Aspect
1	Seeps	N/A
2	Alluvial terrace	N/A
3	Lower slope	NNE, NE
4	Lower slope	N, ENE
5	Lower slope	NNW, E
	Middle slope	NNE, NE
6	Lower slope	NW, ESE
	Middle slope	N, ENE
7	Lower slope	WNW, SE
	Middle slope	NNW, E
	Upper slope	NNE, NE
8	Lower slope	W, SSE
	Middle slope	NNW, E
	Upper slope	NNE, NE
9	Lower slope	WSW, S
	Middle slope	WNW, SE
	Upper slope	NNW, E
10	Lower slope	SW, SSW
	Middle slope	W, SSE
	Upper slope	NW, ESE
11	Middle slope	WSW, S
	Upper slope	WNW, SE
	Ridge	NNE-ENE
12	Middle slope	SW, SSW
	Upper slope	W, SSE
	Ridge	NNE-NW
13	Upper slope	WSW, S
	Ridge	ESE-S
14	Upper slope	SW, SSW
	Ridge	W-WSW
15	Ridge	S-WSW

distances. This information is substantially contained in Appendix B, including the UTM coordinates for polygon centroids.

Historical/Disturbance Data

Crews noted on field forms the presence of atypical features or indications of past uses of the plot, including: "wolf" trees, stumps, fence lines, plow lines, charred trees, and archaeological remains. Crews also noted any "old-growth" characteristic indicators, such as pit and mound topography, large snags, or particularly large diameter trees. Finally, crews noted any negative disturbances at the site, such as trash dumping, shooting, deer browse, trampling, bear scratching, and non-native species invasion.

Data Analysis

Cluster Analysis

The floristic and environmental variables associated with the three relevés contained in each polygon were averaged together to obtain polygon-level measures. The polygon, not the relevé, represented the potential mapping unit of minimum size (0.5 ha) that were developed for the next stage of WNRA's vegetation mapping program, and also for reasons of practicability and to present a general picture of the polygon's species composition (Mueller-Dombois and Ellenberg 1974). Field data were grouped into possible plant associations using a hierarchical clustering algorithm (Euclidean distance, Ward's linkage method) contained in PC-ORD (McCune and Mefford 1999). This algorithm merges individual polygons together into groups based on similarity of species composition. This is in contrast to TWINSPAN (Two-Way Indicator Species Analysis, also contained in PC-ORD), which is a divisive algorithm that splits the entire group of sample polygons into successively smaller clusters of polygons, which at some level are synonymous with associations.

Both kinds of analysis were conducted on the field data, but agglomerative clustering was chosen over TWINSPAN for two reasons. First, McCune and others (2002) strongly warn against the use of TWINSPAN in biological community analysis, pointing out that TWINSPAN performs poorly when the community it analyzes is underlain by more than one important environmental gradient. Second, the clustering algorithm produced groups that were intuitively more coherent than the ones produced by TWINSPAN, thus apparently bearing out McCune's criticisms, since WNRA has a diverse and complex set of vegetation types controlled by several topographic, geologic, and climatic gradients. The data were further resolved through visual inspection of each polygon to compare species abundance and constancy within and between the groups of polygons that PC-ORD had resolved.

Ordination

The polygons were ordinated following classification of vegetation polygons into alliances and associations. Ordination is a method of graphically depicting ecological relationships between plots (Mueller-Dombois and Ellenberg 1974) in such a way that complex multidimensional gradients structuring the vegetation are reduced to two dimensions for ease of interpretation. Ordination is often used as a means of generating hypotheses about natural systems; although the two axes along which vegetation plots are placed are not correlated one-to-one with any particular environmental variables, they may suggest general factors that correspond largely with such variables (McCune and others 2002).

For this study, a method of ordination called Nonmetric Multidimensional Scaling (NMS) was chosen. This is an iterative ordination method that searches for a reduced-dimension representation of a multidimensional space so as to minimize the stress between the reduced-dimensional and full-dimensional spaces, where "stress" indicates a departure from a monotonic relationship between distance in the original space and distance in the reduced-dimensional space. NMS was chosen over other methods of ordination for this study for several reasons. 1) It has performed well in elucidating gradients underlying simulated systems in the past. 2) It does not assume linear relationships among variables. 3) It uses ranked distances, rather than absolute distances, which linearizes the relationship between distances in species space and distances in environmental space. This relieves the common problem that, since species have varying environmental ranges, the full range of environmental space is not reflected in species abundance measures. 4) For the purposes of the ordination any distance measure is usable (McCune and others 2002).

Principal Components Analysis

In his study of Klamath Region vegetation, Whittaker (1960) articulated a conception of vegetation types as reacting in complex and idiosyncratic ways to a number of major intersecting environmental gradients. He hypothesized the two main such gradients in the Klamath Region to be (1) underlying parent materials and (2) change in availability of soil water from west to east and from topographically stable and sheltered sites (such as hollows) to unstable and exposed sites (such as ridges). Most subsequent studies have been conducted in areas so small as to be underlain by only one or two parent material substrates, so that testing of the first factor above is impractical. However, some studies have confirmed the importance of moisture availability as a factor influencing plant growth (Mahony 1999; Sawyer and Thornburgh 1974).

In an attempt to understand which environmental variables appear to be most important in influencing differences in vegetation appearance at WNRA, Principal Components Analysis (PCA) was performed on the environmental variables of this study. PCA is a data analysis technique used to reduce the dimensionality of a data set by combining highly correlated variables into more general factors (the principal components) (Afifi and Clark 1984; Hintze 2001). In this study, principal components analysis was expected to indicate whether a smaller subset of the environmental variables collected were responsible for most of the variation in observed vegetation patterns.

Logistic Regression

In an attempt to further clarify the nature of the axes involved in the ordination of vegetation polygons, logistic regression was used to relate axis direction to vegetation groups. Logistic regression is a way of determining which variables best predict membership in a group, using a group with predetermined membership. It does not require many of the assumptions, such as multivariate normal distribution of variables and a data set composed entirely of continuous-value variables, that are shared by similar techniques such as discriminant analysis (Afifi and Clark 1984; Hintze 2001). For this analysis, each ordination axis was divided in two and the polygons occurring on each side of the division assigned to one group or the other. Logistic regression was then used to determine which variables best predicted membership in one group (i.e., in one direction of environmental variation) or the other.

Riparian plots were not included in PCA or logistic regression analysis, since moisture availability clearly dominates other environmental variables in influencing vegetation patterns around streams. Clustering, ordination, PCA, and logistic regression analysis were all performed on a reduced data set: species occurring in less than 5% of plots were eliminated, and species composing less than 10% total cover across all plots were eliminated. This alleviates the effects of outliers, which can obscure the central tendency of the data (Gauch 1982).

RESULTS

Classification

Examination of the dendrogram produced by hierarchical agglomerative clustering resulted in twenty-two alliances, thirty-nine associations, and ten "types" at WNRA. This dendrogram is shown in Appendix F. The term "type" is a convention adopted to deal with situations where the image-driven sample stratification method delimited an insufficient number of plots in a particular vegetation type to lend confidence that that species assemblage constituted an "association" under NVCS rules. A number of distinct species assemblages were represented by only one polygon. Since each polygon extends beyond the minimum mapping unit of .5 hectare (in most cases well beyond), it was determined that these assemblages do indeed represent distinct plant types on the National Recreation Area that deserve further sampling and study. Therefore, these assemblages were called "types." Vegetation assemblages termed "associations," then, were those that showed consistent physiognomic appearance and species composition over a wide enough spatial extent to be represented by at least two polygons (6 relevés). The table of alliances and associations (Table 4) includes the number of polygons on which a named association was based.

Table 4. NVCS alliances and associations found in the study area. The number of polygons upon which each association name was based follows the association name in parentheses. “Types” were based on one polygon.

Alliance	Association
Alnus rhombifolia temporarily flooded forest	*Alnus rhombifolia / Carex nudata* association (9 polygons)
	Alnus rhombifolia association (7 polygons)
	Alnus rhombifolia / Leucothoe davisiae association (2 polygons)
	Alnus rhombifolia / Pteridium aquilinum association (3 polygons)
Arctostaphylos patula shrubland	*Arctostaphylos patula – Chrysolepis sempervirens / Arctostaphylos nevadensis* association (4 polygons)
Arctostaphylos viscida shrubland	*Arctostphylos viscida – Heteromeles arbutifolia – Toxicodendron diversilobum* type
	Arctostaphylos viscida – Adenostoma fasciculatum association (2 polygons)
Chrysolepis sempervirens shrubland	*Chrysolepis sempervirens – Lithocarpus densiflorus* var. *echinoides* association (4 polygons)
Lithocarpus densiflorus forest	*Lithocarpus densiflorus* var. *densiflorus / Toxicodendron diversilobum* type
	Lithocarpus densiflorus var. *densiflorus – Cornus nuttallii / Toxicodendron diversilobum* association (2 polygons)
Lithocarpus densiflorus var. *echinoides* shrubland	*Lithocarpus densiflorus* var. *echinoides / Pteridium aquilinum* association (5 polygons)
	Lithocarpus densiflorus var. *echinoides / Arctostaphylos nevadensis* type
Pinus attenuata woodland	*Pinus attenuata* – Mixed oak / *Arctostaphylos viscida* association (4 polygons)
	Pinus attenuata / Ceanothus lemmonii association (2 polygons)
Pinus ponderosa forest	*Pinus ponderosa – Lithocarpus densiflorus var. densiflorus – Quercus chrysolepis / Toxicodendron diversilobum* type

Table 4. NVCS alliances and associations found in the study area. The number of polygons upon which each association name was based follows the association name in parentheses. "Types" were based on one polygon (continued).

Alliance	Association
	Pinus ponderosa – Quercus chrysolepis / Arctostaphylos viscida association (2 polygons)
	Pinus ponderosa – Lithocarpus densiflorus var. *densiflorus* association (3 polygons)
Mixed conifer forest	*Abies concolor – Pinus lambertiana – Pinus ponderosa / Lithocarpus densiflorus* var. *echinoides* association (2 polygons)
	Pinus ponderosa – Abies concolor / Arctostaphylos patula – Chrysolepis sempervirens type
	Pinus ponderosa – Pinus lambertiana / Lithocarpus densiflorus var. *echinoides* association (23 polygons)
	Pinus ponderosa – Pinus lambertiana / Arctostaphylos patula – Lithocarpus densiflorus var. *echinoides* association (5 polygons)
	Pinus ponderosa / Lithocarpus densiflorus var. *echinoides* association (2 polygons)
	Pinus ponderosa – Abies concolor / Lithocarpus densiflorus var. *echinoides* association (4 polygons)
	Pinus ponderosa – Pinus lambertiana / Lithocarpus densiflorus var. *echinoides* association (5 polygons)
Pinus ponderosa – Quercus kelloggii woodland	*Pinus ponderosa – Quercus kelloggii / Arctostaphylos viscida – Toxicodendron diversilobum* type
Pinus sabiniana woodland	*Pinus sabiniana – Quercus chrysolepis / Arctostaphylos viscida* association (6 polygons)
Pseudotsuga menziesii giant forest	*Pseudotsuga menziesii – Lithocarpus densiflorus* var. *densiflorus* association (5 polygons)
Pseudotsuga menziesii – Lithocarpus densiflorus forest	*Pseudotsuga menziesii – Lithocarpus densiflorus* var. *densiflorus / Aralia californica* association (4 polygons)

Table 4. NVCS alliances and associations found in the study area. The number of polygons upon which each association name was based follows the association name in parentheses. "Types" were based on one polygon (continued).

Alliance	Association
Pseudotsuga menziesii - Quercus chrysolepis forest	*Pseudotsuga menziesii – Quercus chrysolepis – Acer macrophyllum / Toxicodendron diversilobum* association (6 polygons)
Quercus berberidifolia shrubland	*Quercus berberidifolia – Arctostaphylos patula* type
Quercus chrysolepis forest	*Quercus chrysolepis – Quercus kelloggii / Toxicodendron diversilobum* association (3 polygons)
	Quercus chrysolepis / Styrax officinalis association (2 polygons)
	Quercus chrysolepis / Arctostaphylos viscida association (19 polygons)
	Quercus chrysolepis / Arctostaphylos patula association (4 polygons)
	Quercus chrysolepis / Lithocarpus densiflorus var. echinoides association (2 polygons)
	Quercus chrysolepis / Toxicodendron diversilobum association (2 polygons)
	Quercus chrysolepis / rock association (3 polygons)
	Quercus chrysolepis – Acer macrophyllum / Achnatherum occidentale type
Quercus douglasii woodland	*Quercus douglasii / Cercis occidentalis* type
Quercus garryana var. *garryana* woodland	*Quercus garryana* var. *garryana – Quercus kelloggii / Toxicodendron diversilobum* association (2 polygons)
Quercus garryana var. *breweri* shrubland	*Quercus garryana* var. *breweri – Cercocarpus betuloides* association (2 polygons)
Quercus kelloggii forest	*Quercus kelloggii – Quercus chrysolepis / Heteromeles arbutifolia – Toxicodendron diversilobum* association (3 polygons)
	Quercus kelloggii / Toxicodendron diversilobum association (12 polygons)
	Quercus kelloggii / Heteromeles arbutifolia – Toxicodendron diversilobum association (2 polygons)
	Quercus kelloggii / Arctostaphylos viscida association (3 polygons)

Table 4. NVCS alliances and associations found in the study area. The number of polygons upon which each association name was based follows the association name in parentheses. "Types" were based on one polygon (continued).

Alliance	Association
	Quercus kelloggii – Pinus sabiniana / Styrax officinalis – Toxicodendron diversilobum type
Quercus wislizeni woodland	*Quercus wislizeni / Toxicodendron diversilobum* association (2 polygons)
	Quercus wislizeni / Toxicodendron diversilobum / Centaurea solstitialis association (2 polygons)
	Quercus wislizeni / Arctostaphylos viscida association (4 polygons)

One consistent plant species assemblage that falls within the conventions for naming alliances, but for which no formal alliance has been described in California, is the *Lithocarpus densiflorus* var. *echinoides* shrubland. The following text summarizes the locations, environmental data, and appearances of alliances that were found across the park. So many associations were found that word descriptions of all of them would be impracticable. Assocation descriptions using measures of total cover by species and constancy by species across all plots in the association are found in Tables 5-25.

The definitions of alliances below all follow the nomenclatural rules developed by Sawyer and Keeler-Wolf (in preparation) for the second edition of their *Manual of California Vegetation*, which is designed to crosswalk with National Vegetation Classification System guidelines for alliance names. Two exceptions to this are the *Lithocarpus densiflorus* var. *echinoides* shrubland alliance (mentioned above), and the Mixed Conifer forest alliance, discussed below. Explanations of plant association abbreviations found in all tables are found in Appendix E.

Alnus rhombifolia temporarily flooded forest alliance

(21 polygons)

This alliance is defined as having *Alnus rhombifolia* as "the sole, dominant, or important tree in the canopy along with *Acer macrophyllum* or *Pseudotsuga menziesii.*" At WNRA the alliance comprised stands with >20% relative tree layer cover provided by *Alnus rhombifolia,* sometimes containing *Pseudotsuga menziesii* but not *Lithocarpus densiflorus* var. *densiflorus.* It contained four associations: *Alnus rhombifolia / Carex nudata, Alnus rhombifolia, Alnus rhombifolia / Leucothoe davisiae,* and *Alnus rhombifolia / Pteridium aquilinum* (Table 5). The alliance was found at an average elevation of 362 m (range: 263-1531 m) along southern Boulder Creek, Brandy Creek, and lower Clear Creek southeast of the Whiskeytown reservoir; upper Clear Creek, Grizzly Gulch, Mill Creek and Willow Creek northwest of the reservoir; and northern Boulder Creek and Crystal Creek southwest of the reservoir. Average bank slopes faced faced all aspects and averaged from 1-20%. This alliance was by far the most species-rich of all alliances found in the park. Appearance of the vegetation depends on the size of the stream where it is found; on smaller streams a hardwood canopy including such trees as

Table 5. Mean cover (percentage) and constancy for species used in analysis of *Alnus rhombifolia* temporarily flooded forest alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Alnrho / Carnud*		*Alnrho*		*Alnrho / Leudav*		*Alnrho / Pteaqu*	
	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.
Tree								
Alnus rhombifolia	**19.8**	**100**	**11.9**	**100**	**12.6**	**100**	**54.2**	**100**
Salix lasiolepis	12.4	78			0.1	50		
Quercus chrysolepis	11.2	78	6.0	71			1.6	100
Fraxinus latifolia	4.9	78						
Salix exigua	2.2	56						
Pinus ponderosa	1.8	56					2.3	100
Acer macrophyllum			3.6	57	5.8	50	22.7	100
Aesculus californicus			1.1	57				
Cornus nuttallii					10.8	100	2.8	100
Pseudostsuga menziesii					7.6	100	10.5	100
Salix scouleriana					7.5	50		
Acer glabrum					5	50		
Cornus sericea					2.5	50		
Calocedrus decurrens					1.5	50	10.5	100
Salix laevigata					0.8	50		
Abies concolor					0.3	100	5.5	67
Cornus sessilis							2.8	67
Corylus cornuta							2.7	67
Shrub								
Rubus discolor	28.2	89	12.0	71				
Vitis californica	7	100	0.8	86	0.1	50		
Rubus ursinus	1.7	67	0.7	71			20.5	67
Woodwardia fimbriata	1	67	0.3	57				
Toxicodendron diversilobum	0.8	67	1	86				
Styrax officinalis	0.3	56						
Polystichum munitum	0.2	67	0.08	71	0.1	50	0.3	67
Arctostaphylos viscida			0.4	57				

Table 5. Mean cover (percentage) and constancy for species used in analysis of *Alnus rhombifolia* temporarily flooded forest alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots (continued).

Species	*Alnrho / Carnud*		*Alnrho*		*Alnrho / Leudav*		*Alnrho / Pteaqu*	
	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.
Spiraea douglasii					5	50		
Chrysolepis sempervirens					3.3	50		
Rhododenron occidentale					3.3	50	2.8	67
Pteridium aquilinum					2.8	100	**7.9**	**100**
Leucothoe davisiae					**10.8**	**100**		
Lithocarpus densiflorus var. echinoides					10.1	100	8.3	67
Rubus parviflorus					0.4	100	1.8	67
Rhamnus rubra					0.1	50		
Aralia californica							1.1	67
Ceanothus integerrimus								
Ribes roezlii							2.3	67
Herb								
Carex nudata	**12**	**100**	1.0	57			1.6	67
Darmera peltata	3.8	78	1.2	86	1.6	100		
Equisetum arvense	2.8	67					3.9	100
Datisca glomerata	1.8	56						
Cynosurus echinatus	0.9	67	0.5	71				
Holcus lanatus	0.9	56						
Aira caryophyllea	0.7	78	1	57				
Artemisia douglasiana	0.7	89	0.04	71				
Lotus purshianus	0.7	78			0.1	50		
Panicum acuminatum var. acuminatum	0.6	67						
Juncus effusus	0.6	56						

Table 5. Mean cover (percentage) and constancy for species used in analysis of *Alnus rhombifolia* temporarily flooded forest alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots (continued).

Species	*Alnrho / Carnud*		*Alnrho*		*Alnrho / Leudav*		*Alnrho / Pteaqu*	
	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.
Hypericum perforatum	0.5	100	0.08	57				
Cyperus strigosus	0.5	56						
Torilis arvensis	0.4	67						
Epilobium cilatum	0.4	56						
Lonicera hispidula	0.4	56						
Aristolochia californica	0.3	56						
Rumex salicifolius	0.3	56						
Galium bolanderi	0.09	56						
Elymus glaucus	0.06	67	0.08	57				
Vulpia myuros var. myuros			0.3	57				
Avena fatua			0.005	86				
Scutellaria siphocampy-loides					0.3	50		
Smilacina racemosa					0.28	100		
Aster oregonensis					0.1	50		
Carex rossii					0.1	50		
Juncus covillei					0.1	50		
Lilium pardalinum					0.1	50	0.5	67
Symphoricarpos mollis					0.1	50		
Trientalis latifolia					0.1	50	4.3	67
Dicentra formosa					0.005	100	0.003	67
Asarum hartwegii					0.002	50		
Potentilla glandulosa					0.002	50		
Hieracium albiflorum					0.001	50		
Carex barbarae							0.7	67
Carex geyeri								
Galium aparine							1	67
Smilacina stellata							0.2	67

Alnus rhombifolia, Fraxinus latifolia, Acer macrophyllum, Salix exigua, Salix lasiolepis, and *Cornus* spp. closes over the watercourse, while larger streams typically feature a more open canopy with more widely spaced trees. Often these trees include, along with hardwoods, *Pseudotsuga menziesii* and/or *Quercus chrysolepis* at the tops of steep bank slopes. Vines and brambles of such shrub species as *Rubus discolor, Rubus ursinus,* and *Vitis californica* form dense thickets beneath the canopy at lower elevations, while *Leucothoe davisiae* provides extensive shrub cover at higher elevations. A variety of herbaceous species grows close to the water, especially at lower elevations; these herbs can include *Carex nudata, Darmera peltata, Equisetum arvense,* and *Datisca glomerata.*

<u>*Arctostaphylos patula* shrubland alliance</u>

(4 polygons)

According to the definition of Sawyer and Keeler-Wolf (in preparation), in this alliance "*Arctostaphylos patula* is dominant in the shrub canopy." In stands placed in this alliance at WNRA, *Arctostaphylos patula* provides 30% or greater relative cover within the shrub layer. This alliance contains only one association, the *Arctostaphylos patula – Chrysolepis sempervirens / Arctostaphylos nevadensis* association (Table 6). The alliance was found at an average elevation of 1810 m (range: 1753-1873 m) on both northwest and southeast aspects close to the summit of Shasta Bally. Observed slopes ranged from 30-65%. These sites feature a short shrub layer (~1-1.5 m) that provides continuous

Table 6. Mean cover (percentage) and constancy for species used in analysis of *Arctostaphylos patula* shrubland alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Arcpat - Chrsem / Arcnev*	
	Cover	Constancy
Tree		
Abies concolor	4.2	100
Pinus lambertiana	1.3	67
Shrub		
Arctostaphylos patula	**30.2**	**100**
Arctostaphylos nevadensis	**29.3**	**100**
Chrysolepis sempervirens	**21.2**	**100**
Lithocarpus densiflorus var. *echinoides*	3.6	67
Herb		
Apocynum androsaemifolium	0.6	100
Symphoricarpos mollis	0.4	67

or nearly continuous cover. Widely-spaced conifer saplings, usually *Abies concolor* or *Pinus lambertiana,* punctuate the landscape; most of these saplings are the same height as or slightly higher than the shrub layer. The herbaceous layer consists mainly of *Arctostaphylos nevadensis* cover punctuated by single, widely-spaced herbaceous plants such as *Apocynum androsaemifolium, Pteridium aquilinum,* and *Symphoricarpos mollis.*

<u>*Arctostaphylos viscida* shrubland alliance</u>

(3 polygons)

Like the *Arctostaphylos patula* shrubland alliance, the criterion for the naming of this alliance is that *Arctostaphylos viscida* dominates the shrub canopy. In these stands at WNRA, *Arctostaphylos viscida* provides at least 50% relative cover in the shrub canopy. The alliance contains one type, the *Arctostaphylos viscida – Heteromeles arbutifolia – Toxicodendron diversilobum* type (Table 7), which was observed in one polygon at the northwestern edge of the park near County Line Road. The polygon's elevation was 623 m, and the slope faced southeast. The alliance also contains one association, the *Arctostaphylos viscida – Adenostoma fasciculatum* association (Table 7), found at an average elevation of 477 m (range: 408-545 m) on 20-55% slopes. This association was observed on the south faces of ridges north of Highway 299 between Grizzly Gulch and upper Clear Creek. Although shrub height varies considerably across the alliance, from ~1-3 m, all polygons are almost totally treeless, with shrubs providing 80-100% relative cover. The physiognomy of the alliance ranges from a somewhat open shrubland where *Arctostaphylos viscida* is dominant in patches, but where the structure is interrupted by

Table 7. Mean cover (percentage) and constancy for species used in analysis of *Arctostaphylos viscida* shrubland alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Arcvis - Adefas*		*Arcvis - Hetarb – Toxdiv*[a]
	Cover	Constancy	Cover
Tree			
Pinus sabiniana	0.002	50	
Shrub			
Arctostaphylos viscida	**43.8**	**100**	**87.5**
Adenostoma fasciculatum	**41.3**	**100**	
Heteromeles arbutifolia	2.1	100	**10**
Toxicodendron diversilobum	1.2	100	**10**
Quercus wislizeni	0.5	100	
Styrax officinalis	0.5	50	
Ceanothus lemmonii	0.09	50	
Herb			
Aira caryophyllea	2.2	50	
Galium bolanderi	0.002	50	
Vulpia myuros var. *myuros*	0.0009	50	

[a]No constancy value is supplied because this assemblage is a *type:* it is represented in the study by only one polygon (three relevé plots).

shorter shrubs such as *Adenostoma fasciculatum*, to a shrubland of nearly pure *Arctostaphylos viscida* with a short but distinctive closed canopy and very few plants growing in the dense shade underneath. The only tree observed in any of the plots was *Quercus wislizeni* (seedling). Similarly, almost no herbaceous plants grow in these plots (although some early-spring annuals may grow here, these were unobservable during our sampling season).

Chrysolepis sempervirens shrubland alliance

(4 polygons)

According to the definition of this alliance, *Chrysolepis sempervirens* is dominant in the shrub canopy, and emergent conifer trees may be present. At WNRA, this species provides at least 60% relative cover within the shrub canopy. The alliance is represented at WNRA by one association, the *Chrysolepis sempervirens – Lithocarpus densiflorus* var. *echinoides* association (Table 8), found at the very summit of Shasta Bally (average elevation 1800 m, range 1774-1850 m). The association occupied slopes that faced northeast to southeast with gradients from 25-45%. The alliance appears as an extremely dense shrubland with very sparse emergent conifers such as *Abies concolor* and *Pinus ponderosa,* which for the most part are shorter than or the same height as the shrub canopy.

Table 8. Mean cover (percentage) and constancy for species used in analysis of *Chrysolepis sempervirens* shrubland alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Chrsem - Lideec*	
Tree	Cover	Constancy
Abies concolor	2.2	75
Pinus ponderosa	0.5	50
Shrub		
Chrysolepis sempervirens	**43.0**	**100**
Lithocarpus densiflorus var. *echinoides*	**26.7**	**100**
Arctostaphylos nevadensis	3.1	25
Pteridium aquilinum	2.5	100
Arctostaphylos patula	2.4	50
Leucothoe davisiae	1.1	50
Ceanothus integerrimus	0.1	50
Herb		
Symphoricarpos mollis	0.1	25
Lotus crassifolius	0.1	50
Apocynum androsaemifolium	0.1	50
Iris sp.		

Lithocarpus densiflorus forest alliance

(3 polygons)

This alliance is defined by a dominance of *Lithocarpus densiflorus* var. *densiflorus* in the tree canopy, or, in some situations, a canopy that is composed purely of this species. At WNRA, the alliance comprises stands that feature a canopy with *Lithocarpus densiflorus* var. *densiflorus* contributing at least twice as much relative cover as any other tree species. This alliance contains one type and one association. The *Lithocarpus densiflorus* / *Toxicodendron diversilobum* type (Table 9) was observed on the NE exposure of Salt Gulch, directly south of the road that turns south from Shasta Bally Road and terminates at Brandy Creek. Its observed elevation was 637 m with an 18% slope. The *Lithocarpus densiflorus* – *Cornus nuttallii* / *Toxicodendron diversilobum* association (Table 9) was found at an average elevation of 814 m (range: 664-965 m) on northerly slopes with gradients from 40-60%. All polygons in the alliance were closed forests stocked with trees < 18m tall that provided most of the cover on the plot (>50% absolute cover) and relatively undeveloped shrub and herb layers (<4% and <3% absolute cover, respectively).

Lithocarpus densiflorus var. *echinoides* shrubland alliance

(6 polygons)

This potential alliance has not yet been described in the literature. Although at least one other group of observers has documented the extent of its dominance on Shasta Bally (Mallory and others 1973), they mention *Lithocarpus densiflorus* var. *echinoides*

Table 9. Mean cover (percentage) and constancy for species used in analysis of *Lithocarpus densiflorus* forest alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Lidede / Toxdiv*[a]	*Lidede – Cornut / Toxdiv*	
	Cover	Cover	Constancy
Tree			
Lithocarpus densiflorus var. *densiflorus*	**79.2**	**45.8**	**100**
Quercus kelloggii	6.7	2.8	100
Pseudotsuga menziesii	3.3	10.7	100
Acer macrophyllum	3.3	3.4	100
Pinus ponderosa	3.3	2.2	50
Cornus sericea	2.0		
Quercus chrysolepis	0.2	1.1	100
Cornus nuttallii		**13.3**	**100**
Pinus lambertiana		0.1	50
Calocedrus decurrens		0.5	50
Shrub			
Toxicodendron diversilobum	**1.0**	**1.1**	**50**
Pteridium aquilinum	1.0	0.002	50
Vitis californica	1.0		
Polystichum munitum		0.002	50
Herb			
Iris sp.		0.1	50
Apocynum androsaemifolium		0.1	50
Symphoricarpos mollis		0.002	50

[a]No constancy value is supplied because this assemblage is a *type:* it is represented in the study by only one polygon (three relevé plots).

only in association with conifer species. At WNRA, this alliance name denotes pure shrublands (or some with extremely widely spaced old or emergent conifers), the shrub layer of which is composed of at least 50% *Lithocarpus densiflorus* var. *echinoides* with abundance measured as relative cover within the layer. The stands of *Lithocarpus densiflorus* var. *echinoides* by which this potential alliance was named occur on all aspects of Shasta Bally. A *Lithocarpus densiflorus / Arctostaphylos nevadensis* type (Table 10) was observed on a southeast-facing, 45% slope just north of the summit of Shasta Bally; the two shrubs that give the type its name provide >90% of the shrub cover, with a few short (~3m) *Abies concolor* and *Pinus ponderosa* seedlings growing above the shrub layer. The rest of the alliance consists of the *Lithocarpus densiflorus* var. *echinoides / Pteridium aquilinum* association (Table 10), of which four polygons were >80% covered by continuous *Lithocarpus* with sparse but constant *Pteridium* and a fifth equally dominated by *Lithocarpus* and *Pteridium.* Very little conifer cover was present in this association, and the seedlings present did not overtop the shrub layer, with the exception of the polygon that was equally dominated by *Lithocarpus* and *Pteridium,* which had a few scattered specimens of *Pinus ponderosa, Pinus lambertiana,* and *Calocedrus decurrens* with a maximum height of ~7m. This association was found on 25-60% slopes at an average elevation of 1522m (range: 1359-1730m); the plots dominated mostly by *Lithocarpus* were all found near the summit of Shasta Bally, while the polygon

Table 10. Mean cover (percentage) and constancy for species used in analysis of *Lithocarpus densiflorus* var. *echinoides* shrubland alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Lideec / Pteaqu*		*Lideec / Arcnev*[a]
	Cover	Constancy	Cover
Tree			
Pinus lambertiana	1.1	60	
Abies concolor	0.3	80	3.3
Pinus ponderosa			1
Shrub			
Lithocarpus densiflorus var. *echinoides*	**73.5**	**100**	**48.3**
Chrysolepis sempervirens	6.5	60	7.7
Pteridium aquilinum	**6.1**	**80**	
Arctostaphylos patula	0.9	60	2
Arctostaphylos nevadensis			**50**
Herb			
Lotus crassifolius			0.4
Holodiscus discolor			0.2
Apocynum androsaemifolium			0.2
Symphoricarpos mollis			0.2
Carex rossii			0.003
Erigeron inornatus			0.003

[a]No constancy value is supplied because this assemblage is a *type:* it is represented in the study by only one polygon (three relevé plots).

dominated equally by *Lithocarpus* and *Pteridium* was found to the west of the mountain on the east side of County Line Road.

Pinus attenuata woodland alliance

(6 polygons)

The definition for this alliance states that *Pinus attenuata* is sole or dominant in the tree canopy. The alliance name is used at WNRA for stands with *Pinus attenuata* providing at least 10% relative cover in the tree canopy and emerging above the other trees, creating a two-tiered canopy. The alliance contains two associations: the *Pinus attenuata* – Mixed oak / *Arctostaphylos viscida* association and the *Pinus attenuata / Ceanothus lemmonii* association (Table 11). The alliance was found at an average elevation of 338m (range: 325-359m) on primarily south-facing slopes with gentle gradients (5-25%). All polygons in this alliance were relatively close to Whiskeytown Reservoir (<3000m horizontal distance); five of them were located southeast of the reservoir in the drainages of lower Clear Creek and its tributaries, while one was located north of the reservoir at the mouth of Whiskey Gulch. The alliance as typified at WNRA is marked by a preponderance of shrub cover, with the principal shrubs (*Ceanothus lemmonii, Arctostaphylos viscida, Heteromeles arbutifolia,* and *Toxicodendron diversilobum*) growing 1-3m in height and providing 45-75% absolute cover. Tree cover varies greatly in the *Pinus attenuata / Ceanothus lemmonii* association because of extensive knobcone blowdown that has apparently succeeded to *Ceanothus lemmonii*; this association features isolated strips and patches of both surviving mature

Table 11. Mean cover (percentage) and constancy for species used in analysis of *Pinus attenuata* woodland alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Pinatt* – MO / *Arcvis*		*Pinatt / Cealem*	
	Cover	Constancy	Cover	Constancy
Tree				
Quercus chrysolepis	**9.5**	**100**		
Quercus kelloggii	**9.3**	**100**	5.6	100
Quercus wislizeni	**8.1**	**100**	0.1	50
Pinus attenuata	**5.5**	**100**	**3.8**	**100**
Quercus douglasii	1.1	50		
Pinus sabiniana	0.9	50		
Pinus ponderosa			2.7	50
Shrub				
Arctostaphylos viscida	**27**	**100**	10.1	100
Heteromeles arbutifolia	8.5	100	12.2	100
Toxicodendron diversilobum	3.6	100	3.4	100
Styrax officinalis	2.9	100	1.6	100
Ceanothus lemmonii	1.2	75	**34.2**	**100**
Cercis occidentalis			1.7	50
Herb				
Aira caryophyllea	6	100	4.5	100
Symphoricarpos mollis	0.1	100	0.1	50
Galium bolanderi	0.05	50	0.4	100
Aristolochia californica	0.05	50	0.002	50
Vulpia myuros var. *myuros*	0.05	75	0.002	50
Achnatherum occidentale	0.003	75	0.2	100
Cynosurus echinatus	0.002	50		
Torilis arvensis	0.001	50		
Eriodictyon californicum			1.6	100
Iris sp.			0.002	50
Vulpia microstachys			0.002	50

Pinus attenuata trees and mature *Quercus kelloggii* trees. Tree cover is somewhat more extensive in the *Pinus attenuata – Quercus kelloggii / Arctostaphylos viscida* association, including both more hardwoods (*Quercus kelloggii, Quercus chrysolepis, Quercus wislizeni)* and more conifers (*Pinus attenuata, Pinus sabiniana).* Herbaceous cover is extensive and species-rich—more so in the area disturbed by blowdown than in the other areas—and includes large, continuous areas of *Aira caryophyllea* as well as small amounts of such species as *Hypericum perforatum, Hypericum concinnum, Symphoricarpos mollis, Galium bolanderi, Wyethia glabra,* and *Achnatherum occidentale.*

Pinus ponderosa forest alliance

(6 polygons)

This alliance is defined as having "*Pinus ponderosa* [the] sole, dominant or important tree with *Quercus chrysolepis* or *Q. wislizenii* in canopy." At WNRA it is composed of stands with *Pinus ponderosa* providing at 15% relative cover in the tree layer and with the conifers growing above the hardwoods in a two-tiered canopy. The alliance contains one type, *Pinus ponderosa – Lithocarpus densiflorus – Quercus chrysolepis / Toxicodendron diversilobum*, and two associations, *Pinus ponderosa – Quercus chrysolepis / Arctostaphylos viscida* and *Pinus ponderosa – Lithocarpus densiflorus / Iris* (Table 12). The polygons containing this alliance were found along Boulder Creek (near the Paige-Bar Road immediately south of the reservoir), south of

Table 12. Mean cover (percentage) and constancy for species used in analysis of *Pinus ponderosa* forest alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Pinpon - Lidede - Quechr / Toxdiv*[a]	*Pinpon - Quechr / Arcvis*		*Pinpon - Lidede*	
	Cover	Cover	Constancy	Cover	Constancy
Tree					
Lithocarpus densiflorus var. *densiflorus*	**33.3**			**19.8**	**100**
Quercus chrysolepis	**25**	**21.3**	**100**	8.0	100
Pinus ponderosa	**12.5**	**7.7**	**100**	**18.6**	**100**
Quercus kelloggii	10	17.1	100	2.8	100
Pseudotsuga menziesii	8.7			4.7	100
Cornus sericea	1				
Quercus wislizeni	0.2				
Pinus attenuata		5.5	50		
Quercus douglasii		2.2	50		
Cornus nuttallii		1.0	50		
Calocedrus decurrens				3	100
Pinus lambertiana				2.1	67
Shrub					
Toxicodendron diversilobum	**22.5**	6.6	100	0.7	67
Arctostaphylos viscida	1.2	**11.7**	**100**		
Cercis occidentalis	1				
Holodiscus discolor	1				
Vitis californica	1				
Polystichum munitum	0.4	0.5	50	0.1	67
Rubus ursinus	0.2	0.002	50		
Styrax officinalis		2.2	50		
Pteridium aquilinum		0.6	50	0.8	100
Heteromeles arbutifolia		0.6	50		
Ceanothus lemmonii		0.5	50		
Ceanothus integerrimus		0.2	100		
Herb					
Apocynum androsaemifolium	2.2	0.6	50		
Aristolochia californica	0.6				
Galium bolanderi	0.2	2.1	100		

Species	*Pinpon - Lidede - Quechr / Toxdiv*[a]	*Pinpon - Quechr / Arcvis*		*Pinpon - Lidede*	
	Cover	Cover	Constancy	Cover	Constancy
Iris sp.	0.01	1.8	100	0.3	100
Symphoricarpos mollis	0.003	.005	100		
Vulpia microstachys		6.3	100		
Aira caryophyllea		3.4	100		
Achnatherum occidentale		2.9	100		
Eriodictyon californicum		0.6	50		
Wyethia angustifolia		0.6	50		
Vulpia myuros var. *myuros*		0.1	100		
Torilis arvensis		.005	100		

[a]No constancy value is supplied because this assemblage is a *type:* it is represented in the study by only one polygon (three relevé plots).

Shasta Bally road at various elevations from 600-1350 m, and along Mill Creek Road southwest of Carr Powerhouse. The alliance was found on north- to east-facing slopes of 5-75% at an average elevation of 874 m (range: 426-1322 m). The alliance consists of closed forests with *Pinus ponderosa* providing 7-25% absolute cover and various hardwoods (principally the ones in the association names) contributing equal to five times as much cover but in a lower stratum of the canopy.

Mixed conifer forest alliance

(42 polygons)

In these stands at WNRA, either *Pinus ponderosa* or *Abies concolor* provides at least 20% relative cover in the tree layer. *Pinus lambertiana* is also always present, although it may not be abundant. The mixed conifer forest alliance consists of one type and five associations, all extremely alike in appearance, varying mainly in species composition. This alliance has has been renamed in most of the existing literature. Sawyer and Keeler-Wolf (in preparation) place mixed conifer stands in their *Pinus ponderosa – Calocedrus decurrens* alliance. However, at WNRA these "mixed conifer" stands have very little (if any) cover contributed by *Calocedrus decurrens*. Therefore, the *Pinus ponderosa – Calocedrus decurrens* name was judged insufficiently descriptive for this alliance. National Vegetation Classification Standards do not yet list any kind of mixed conifer alliance in their hierarchies (Environmental Systems Research Institute and Nature Conservancy 1994). The type contained within this alliance at WNRA is the *Pinus ponderosa – Abies concolor / Arctostaphylos patula – Chrysolepis sempervirens* type; the associations are *Abies concolor – Pinus lambertiana – Pinus ponderosa / Lithocarpus* *densiflorus* var. *echinoides, Pinus ponderosa – Pinus lambertiana / Lithocarpus densiflorus* var. *echinoides, Pinus ponderosa – Pinus lambertiana / Arctostaphylos patula – Lithocarpus densiflorus* var. *echinoides, Pinus ponderosa – Abies concolor / Lithocarpus densiflorus* var. *echinoides,* and *Pinus ponderosa – Pinus lambertiana / Lithocarpus densiflorus* var. *echinoides* (Table 13). The type and all the associations were found either at the summit of Shasta Bally or along the road immediately to the west. They were found at an average elevation of 1483 m (range: 1229-1701 m) on primarily north- and east-facing slopes (*Pinus ponderosa / Arctostaphylos patula – Lithocarpus densiflorus* var. *echinoides* on east to southeast slopes) with gradients ranging from 10-85%. At WNRA these stands can appear as near-woodlands typically characterized by very dense shrub cover with small (~7 m) conifers frequent across the landscape and very large, old conifers spaced 15-30 m or more apart. Ephemeral drainages is this near-woodland type are often characterized by the presence of denser groves (typically scattered groups three-four closely spaced larger trees) of conifers and riparian shrubs and herbs.

Pinus ponderosa – Quercus kelloggii woodland alliance

(1 polygon)

This alliance is characterized by canopy dominance shared between the two named species. At WNRA, *Pinus ponderosa* contributes at least 30% relative cover to the stands in this alliance and forms a separate canopy tier above *Quercus kelloggii*, which

Table 13. Mean cover (percentage) and constancy for species used in analysis of mixed conifer forest alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Abicon – Pinlam – Pinpon / Lideec*		*Pinpon– Abicon / Arcpat – Chrsem*[a]	*Pinpon - Pinlam / Lideec*		*Pinpon – Pinlam / Arcpat - Lideec*		*Pinpon / Lideec*		*Pinpon - Abicon / Lideec*		*Pinpon - Pinlam / Lideec*	
	Cover	Const.	Cover	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.
Tree													
Pinus ponderosa	**6.7**	**67**	**10**	**9.1**	**91**	**14.4**	**100**	**11.8**	**100**	**21.1**	**100**	**15.1**	**100**
Abies concolor	**27.8**	**100**	**6.7**	3.9	91	1.6	80	1.9	100	**19.3**	**100**	0.8	60
Pinus lambertiana	**9.9**	**100**	1	**6.1**	**100**	**8.3**	**100**	1.7	50	2.2	100	**7.2**	**100**
Cornus nuttallii	2.2	67		0.7	52					6	100		
Calocedrus decurrens	8.8	100				1.1	100						
Pseudotsuga menziesii								1.7	50	3	75		
Quercus chrysolepis								1.2	100			13.4	60
Shrub													
Arctostaphylos patula	2.9	67	**54.2**	5.2	83	**35.2**	**100**	1.7	100	0.8	50	0.5	60
Chrysolepis sempervirens			**42.5**	4.5	57					0.5	50		
Lithocarpus densiflorus var. *echinoides*	**46.7**	**100**	5.3	**66.2**	**96**	**14.1**	**100**	**8.9**	**100**	**77.1**	**100**	**67.5**	**100**
Ceanothus prostratus			2			7.7	80	0.3	50				

Table 13. Mean cover (percentage) and constancy for species used in analysis of mixed conifer forest alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots (continued).

Species	*Abicon – Pinlam – Pinpon / Lideec*		*Pinpon / Arcpat – Chrsem*[a]	*Pinpon - Pinlam - Abicon / Lideec*		*Pinpon / Arcpat - Lideec*		*Pinpon / Lideec*		*Pinpon - Abicon / Lideec*		*Pinpon - Pinlam / Lideec*	
	Cover	Const.	Cover	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.
Arctostaphylos nevadensis			2					1.7	50				
Pteridium aquilinum	0.8	100		0.2	57			0.1	50	1.1	75		
Ceanothus lemmonii								0.002	50				
Herb													
Lotus crassifolius	0.1	67	0.2	0.3	61	0.5	60	0.1	50	0.4	50		
Apocynum androsaemifolium	0.1	67	0.01	0.05	78			0.003	50	0.1	75		
Iris sp.	0.005	67				0.1	80	0.6	50	0.006	100	0.1	60
Achnatherum occidentale								0.002	50				
Glium bolanderi								0.003	50				
Symphoricarpos mollis			0.1	67						0.1	50		
Vulpia microstachys								0.1	50				

[a]No constancy value is supplied because this assemblage is a *type:* it is represented in the study by only one polygon (three relevé plots).

Table 14. Mean cover (percentage) for species used in analysis of *Pinus ponderosa* – *Quercus kelloggii* woodland alliance.

Species	*Pinpon - Quekel / Arcvis – Toxdiv*[a]
	Cover
Tree	
Quercus kelloggii	**28.3**
Pinus ponderosa	**25.8**
Quercus chrysolepis	5.3
Acer macrophyllum	0.2
Aesculus californicus	0.2
Quercus wislizeni	0.2
Shrub	
Arctostaphylos viscida	**14.5**
Toxicodendron diversilobum	**14.3**
Heteromeles arbutifolia	13.3
Cercis occidentalis	4.5
Ceanothus integerrimus	1.0
Vitis californica	1.0
Styrax officinalis	0.6
Herb	
Aristolochia californica	4.3
Galium bolanderi	2.2
Symphoricarpos mollis	0.6
Achnatherum occidentale	0.2
Torilis arvensis	0.2
Aira caryophyllea	0.003
Vulpia microstachys	0.003

[a]No constancy value is supplied because this assemblage is a *type:* it is represented in the study by only one polygon (three relevé plots).

also provides at least 30% relative cover. The alliance is represented at WNRA by one type: *Pinus ponderosa – Quercus kelloggii / Arctostaphylos viscida – Toxicodendron diversilobum* (Table 14). This type was observed just southwest of upper Clear Creek~1000 m downstream of its intersection with Highway 299 (northwest of the reservoir). Its elevation was 434 m. The bank slope was 30% and faced east. The type was a closed-canopy forest with well-developed tree (70% absolute cover), shrub (66% absolute cover), and herb (10% absolute cover) strata.

<u>*Pinus sabiniana* woodland alliance</u>

(6 polygons)

The definition for this alliance states that *Pinus sabiniana* is dominant within the tree canopy. At WNRA the stands in this alliance contain at least 10% *Pinus sabiniana* cover (relative) in the tree canopy. One association falls within this alliance on WNRA, *Pinus sabiniana – Quercus chrysolepis / Arctostaphylos viscida* association (Table 15). This association was found at an average elevation of 320 m (range: 297-354 m) on east and southeast-facing aspects. Slopes ranged from 25-70%. The *Pinus sabiniana – Quercus chrysolepis / Arctostaphylos viscida* association was found on the western side of lower Clear Creek toward the southern boundary of the park. The woodlands in the alliance tend to feature sparse tree cover with a preponderance of shrubs.

Table 15. Mean cover (percentage) and constancy for species used in analysis of *Pinus sabiniana* woodland alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Pinsab - Quechr / Arcvis*	
	Cover	Constancy
Tree		
Quercus chrysolepis	**15.9**	**100**
Quercus kelloggii	7.8	100
Pinus sabiniana	**6.1**	**100**
Quercus wislizeni	3.9	83.3
Aesculus californicus	0.9	50
Shrub		
Arctostaphylos viscida	**15.5**	**100**
Heteromeles arbutifolia	10.5	100
Toxicodendron diversilobum	4.3	100
Styrax officinalis	2.2	100
Ceanothus lemmonii	1.6	66.7
Herb		
Aira caryophyllea	2.0	100
Cynosurus echinatus	1	83.3
Galium bolanderi	0.5	100
Torilis arvensis	0.2	100
Symphoricarpos mollis	0.1	83.3
Vulpia myuros var. *myuros*	0.07	83.3
Achnatherum occidentalis	0.002	50

<u>*Pseudotsuga menziesii* giant forest alliance</u>

(5 polygons)

This alliance name pertains to forests in which *Pseudotsuga menziesii* is the sole or clearly dominant tree in the canopy. On WNRA this alliance name refers to stands the tree layer of which is composed of at least 75% *Pseudotsuga menziesii* measured as relative cover; it is represented by one association, the *Pseudotsuga menziesii – Lithocarpus densiflorus* association (Table 16). This association was found at an average elevation of 898 m (range: 702-1128 m) on northerly slopes with gradients ranging from 35-65%. It was found in a number of scattered locations: along Shasta Bally Road and south of Peltier Valley Road in the south-central portion of the park and west of County Line Road close to the extreme western boundary of the park. The association was composed exclusively of closed-canopy forests with very open understories. *Pseudotsuga menziesii* contributed by far the greatest proportion of cover—roughly two-thirds—with *Pinus ponderosa* and various hardwoods (*Lithocarpus densiflorus, Quercus chrysolepis, Quercus kelloggii*) contributing the remaining third.

<u>*Pseudotsuga menziesii – Lithocarpus densiflorus* forest alliance</u>

(4 polygons)

This alliance is characterized by co-dominance of the two above-named species in the canopy. In stands placed under this alliance at WNRA, *Pseudotsuga menziesii* provides at least 10% relative cover in the tree canopy and emerges above a primarily hardwood canopy that contains at least 25% relative cover contributed by *Lithocarpus densiflorus*

Table 16. Mean cover (percentage) and constancy for species used in analysis of *Pseudotsuga menziesii* giant forest alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Psemen - Lidede*	
	Cover	Constancy
Tree		
Pseudotsuga menziesii	**50.7**	**100**
Quercus chrysolepis	16.1	100
Lithocarpus densiflorus var. *densiflorus*	**10.7**	**100**
Pinus ponderosa	10.1	100
Quercus kelloggii	6.9	80
Cornus nuttallii	3.9	80
Calocedrus decurrens	2.4	100
Shrub		
Polystichum munitum	0.08	60
Herb		
Iris sp.	0.08	100

Table 17. Mean cover (percentage) and constancy for species used in analysis of *Pseudotsuga menziesii – Lithocarpus densiflorus* forest alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Psemen - Lidede / Aracal*	
	Cover	Constancy
Tree		
Lithocarpus densiflorus var. *densiflorus*	**26.3**	**100**
Alnus rhombifolia	15.3	50
Cornus sessilis	13.1	50
Pseudotsuga menziesii	**12.6**	**100**
Acer macrophyllum	12.1	100
Quercus chrysolepis	4.3	100
Calocedrus decurrens	2.1	75
Cornus nuttallii	1.1	50
Pinus lambertiana	0.4	75
Shrub		
Aralia californica	**4.1**	**100**
Rubus ursinus	2.9	75
Toxicodendron diversilobum	1.8	100
Woodwardia fimbriata	1.6	100
Polystichum munitum	0.6	100
Pteridium aquilinum	0.2	75
Ribes roezlii	0.1	50
Herb		
Equisetum arvense	1.7	50
Darmera peltata	0.8	75
Trientalis latifolia	0.8	75
Lonicera hispidula	0.6	50
Mentha arvensis	0.5	50
Smilacina racemosa	0.1	50
Smilacina stellata	0.001	50

var. *densiflorus*. The association on WNRA that falls into this category, the *Pseudotsuga menziesii – Lithocarpus densiflorus / Aralia californica* association (Table 17), is a riparian association that was observed along three creeks: the northern part of Boulder Creek and Mill Creek west of Whiskeytown Reservoir and Brandy Creek along the Brandy Falls Trail south of Shasta Bally Road. It was observed at an average elevation of 665 m (range: 596-760 m) on northeast- and southeast-facing banks with slopes ranging from 10-30%. The canopy is relatively closed; along Brandy Creek, but not the other two creeks, *Alnus rhombifolia* is an important canopy component along with *Lithocarpus* and *Pseudotsuga*. Various other mesophytic trees and shrubs, such as *Cornus sessilis, Cornus sericea, Acer macrophyllum, Aralia californica,* and *Woodwardia fimbriata* are also present as well as a species-rich herbaceous layer.

<u>*Pseudotsuga menziesii – Quercus chrysolepis* forest alliance</u>

(6 polygons)

The definition of this alliance is identical to that of the preceding alliance, except with *Quercus chrysolepis* rather than *Lithocarpus* co-dominant in the tree canopy with *Pseudotsuga menziesii*. At WNRA, each of these species contributes at least 30% relative cover to the tree canopy. The alliance contains one association at WNRA, *Pseudotsuga menziesii – Quercus chrysolepis – Acer macrophyllum / Toxicodendron diversilobum* (Table 18). This association was found mostly southeast of Shasta Bally Road but also directly south of Carr Powerhouse on the southwest side of Whiskeytown Reservoir and

Table 18. Mean cover (percentage) and constancy for species used in analysis of *Pseudotsuga menziesii – Quercus chrysolepis* forest alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Psemen - Quechr- Acemac / Toxdiv*	
	Cover	Constancy
Tree		
Quercus chrysolepis	**19.1**	**100**
Pseudotsuga menziesii	**18.4**	**100**
Acer macrophyllum	**10.7**	**100**
Quercus kelloggii	5.7	100
Lithocarpus densiflorus var. *densiflorus*	3.9	100
Pinus ponderosa	3.5	40
Cornus sericea	2.2	40
Corylus cornuta	2.2	40
Cornus nuttallii	1.7	60
Pinus attenuata	1.3	20
Pinus lambertiana	0.5	40
Calocedrus decurrens	0.4	40
Shrub		
Toxicodendron diversilobum	**3.2**	**100**
Rubus ursinus	3.2	20
Vitis californica	1.7	60
Arctostaphylos viscida	1.3	20
Polystichum munitum	1.2	100
Philadelphus lewisii	0.9	40
Holodiscus discolor	0.7	40
Pteridium aquilinum	0.3	100
Heteromeles arbutifolia	0.04	40
Ceanothus integerrimus	0.04	40
Herb		
Galium bolanderi	0.04	20
Iris sp.	0.04	100
Achnatherum occidentale	0.001	20
Aristolochia californica	0.001	40
Symphoricarpos mollis	0.001	20
Torilis arvensis	0.0004	20

on the east side of County Line Road toward the western boundary of the park. It as found at an average elevation of 697 m (range: 462-996 m) on northwest-, northeast-, and southeast-facing slopes with gradients ranging from 35-60%. It consists of forests with mostly closed canopies but variable understories: some polygons featured very little shrub and herb development, while others contained extremely dense understories. *Toxicodendron diversilobum* accounted for a significant portion of this growth in several polygons. The occurrence of *Acer macrophyllum* on all sites and of *Rubus ursinus, Corylus cornuta, Cornus nuttallii,* and *Polystichum munitum* on several sites points to their mesic character.

Quercus berberidifolia shrubland alliance

(1 polygon)

In this alliance *Quercus berberidifolia* is the sole or dominant shrub in the shrubland canopy. In the stands placed under this alliance at WNRA, *Quercus berberidifolia* provides at least 60% cover within the shrub canopy. The alliance is represented by one type at WNRA, the *Quercus berberidifolia – Arctostaphylos patula* type (Table 19). This site, which was observed to the southwest of the summit of Shasta Bally, was extremely depauperate, with only six species present: *Quercus berberidifolia* (63% absolute cover), *Arctostaphylos patula* (19% absolute cover), *Lithocarpus densiflorus* var. *echinoides, Ceanothus prostratus, Pinus ponderosa* (seedlings), and *Chrysolepis sempervirens.* The observed elevation was 1804 m, the slope 65% and facing southeast.

Table 19. Mean cover (percentage) for species used in analysis of *Quercus berberidfolia* shrubland alliance.

Species	*Queber – Arcpat*[a]
	Cover
Shrub	
Quercus berberidifolia	**62.5**
Arctostaphylos patula	**19.2**
Lithocarpus densiflorus var. echinoides	5.3
Ceanothus prostratus	4.5
Chrysolepis sempervirens	1
Pinus ponderosa	1

[a]No constancy value is supplied because this assemblage is a *type:* it is represented in the study by only one polygon (three relevé plots).

<u>*Quercus chrysolepis* forest alliance</u>

(36 polygons)

This alliance is defined as having *Quercus chrysolepis* as the sole, dominant, or important tree in the canopy with *Arbutus menziesii, Lithocarpus densiflorus, Pinus lambertiana,* or *Quercus garryana*. At WNRA the alliance contains stands in which *Quercus chrysolepis* contributes at least 50% relative cover, and often over 75%, to the tree canopy. It is the largest one in terms of associations found across WNRA, with seven associations and one type: *Quercus chrysolepis – Quercus kelloggii / Toxicodendron diversilobum, Quercus chrysolepis / Styrax officinalis, Quercus chrysolepis / Arctostaphylos viscida, Quercus chrysolepis / Arctostaphylos patula, Quercus chrysolepis / Lithocarpus densiflorus* var. *echinoides, Quercus chrysolepis / Toxicodendron diversilobum, Quercus chrysolepis* (associations), and *Quercus chrysolepis – Acer macrophyllum / Achnatherum occidentale* (type) (Table 20). The alliance is ubiquitous across the park. Observed elevations ranged from an average of 335 m for the *Quercus chrysolepis – Quercus kelloggii / Styrax officinalis* association to an average of 1751 m for the *Quercus chrysolepis / Arctostaphylos patula* association. Observed slopes ranged from 20-70%, and every aspect was represented. See the discussion below for further analysis of this alliance.

Table 20. Mean cover (percentage) and constancy for species used in analysis of *Quercus chrysolepis* forest alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Quechr - Quekel / Toxdiv*		*Quechr / Styoff*		*Quechr / Arcvis*		*Quechr / Arcpat*		*Quechr / Lideec*		*Quechr / Toxdiv*		*Quechr*		*Quechr - Acemac / Achocc*[a]
	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover
Tree															
Quercus chrysolepis	**30.6**	**100**	**58.3**	**100**	**19**	**100**	**35**	**100**	**23.3**	**100**	**87.5**	**100**	**79.2**	**100**	**62.5**
Quercus kelloggii	**25.6**	**100**	18.5	100	8.9	100							1.1	67	
Aesculus californicus	7.1	67	4.4	100							1.8	50			4.5
Pinus ponderosa	1.3	67	0.003	50					0.6	50					3.5
Pinus sabiniana			0.5	100											
Quercus wislizeni			0.1	50											
Abies concolor									0.2	50					
Acer macrophyllum											0.5	50			**12.5**
Pinus attenuata					1.5	53									
Pinus lambertiana									1.2	100					
Pseudotsuga menziesii											1.7	50			
Quercus garryana															16.8

Table 20. Mean cover (percentage) and constancy for species used in analysis of *Quercus chrysolepis* forest alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots (continued).

Species	*Quechr - Quekel / Toxdiv*		*Quechr / Styoff*		*Quechr / Arcvis*		*Quechr / Arcpat*		*Quechr / Lideec*		*Quechr / Toxdiv*		*Quechr*		*Quechr - Acemac / Achocc*[a]
	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover
Shrub															
Toxicodendron diversilobum	**33.9**	**100**	8.7	100	2.3	90					**15**	**100**	0.6	67	0.4
Arctostaphylos viscida	1.1	100	1.5	100	**43**	**100**							0.002	67	
Vitis californica	0.3	33													
Polystichum munitum	0.1	67	0.7	100							0.002	50			0.4
Cercis occidentalis	0.1	67									1.5	100			
Styrax officinalis			**29.6**	**100**	3.8	95									0.2
Heteromeles arbutifolia			7.7	100	6.8	100									
Ceanothus integerrimus			0.2	100					0.6	50					0.2
Cercocarpus betuloides			0.1	50											1
Pteridium aquilinum									1	50					
Arctostaphylos patula							**24**	**100**	19.4	100					

Table 20. Mean cover (percentage) and constancy for species used in analysis of *Quercus chrysolepis* forest alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots (continued).

Species	*Quechr - Quekel / Toxdiv*		*Quechr / Styoff*		*Quechr / Arcvis*		*Quechr / Arcpat*		*Quechr / Lideec*		*Quechr / Toxdiv*		*Quechr*		*Quechr - Acemac / Achocc*[a]
	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover
Ceanothus prostratus							4.9	100	3.7	100					
Holodiscus discolor							0.4	75							
Lithocarpus densiflorus var. echinoides							4.9	75	**36.7**	**100**					
Herb															
Achnatherum occidentale	0.7	67	1	100							0.5	50			**11**
Iris sp.	0.3	67	0.8	100					0.1	50					0.6
Aira caryophyllea	0.001		0.2	50	0.5	79									1
Galium bolanderi	.006	67	2.9	100	0.04	79					0.1	100			0.2
Wyethia angustifolia			6.9	100											
Aristolochia californica			0.7	100											

Table 20. Mean cover (percentage) and constancy for species used in analysis of *Quercus chrysolepis* forest alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots (continued).

Species	*Quechr - Quekel / Toxdiv*		*Quechr / Styoff*		*Quechr / Arcvis*		*Quechr / Arcpat*		*Quechr / Lideec*		*Quechr / Toxdiv*		*Quechr*		*Quechr - Acemac / Achocc*[a]
	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover	Const.	Cover
Vulpia microstachys			0.6	50											0.003
Torilis arvensis			0.4	100							0.002	50			0.4
Cynosurus echinatus			0.1	50											
Vulpia myuros var. myuros			0.003	100	0.1	68									0.002
Apocynum androsaemifolium									0.7	100					
Lotus crassifolius							0.05	50	0.3	100					

[a]No constancy value is supplied because this assemblage is a *type:* it is represented in the study by only one polygon (three relevé plots).

<u>*Quercus douglasii* woodland alliance</u>
(1 polygon)

This alliance is defined as having *"Quercus douglasii* sole, dominant, or important with *Juniperus californica, Pinus sabiniana, Q. agrifolia, Q. lobata,* or *Q. wislizeni* in the tree canopy." At WNRA the alliance name applies to stands in which *Quercus douglasii* provides >60% relative cover within the tree canopy. The alliance as it is expressed in this study at WNRA—in a single type, the *Quercus douglasii / Cercis occidentalis* type (Table 21)—does not contain any of the trees mentioned in the definition, but it does contain a high proportion of *Quercus chrysolepis* (~33% relative cover). The alliance was observed on the west side of County Line Road; it occupied the south-facing slope of an east-west tending drainage, the opposite face being occupied by the *Quercus chrysolepis – Quercus kelloggii / Toxicodendron diversilobum* association. The elevation was 526 m, and the slope measured 46%. The four species identified in the type name provided almost all the cover, along with a small amount of *Styrax officinalis, Aesculus californica, Quercus kelloggii,* and a few other xerophytic shrubs and non-native herbs (e.g., *Cynosurus echinatus*).

<u>*Quercus garryana* var. *garryana* woodland alliance</u>

(2 polygons)

According to the definition, in this alliance *Quercus garryana* var. *garryana* can be dominant in the tree canopy, or it can share importance with *Quercus kelloggii* or *Pseudotsuga menziesii.* At WNRA *Quercus garryana* var. *garryana* provides at least 40% relative

Table 22. Mean cover (percentage) and constancy for species used in analysis of *Quercus garryana* var. *garryana* woodland alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Quegar - Quekel / Toxdiv*	
	Cover	Constancy
Tree		
Quercus garryana var. *garryana*	**26.8**	**100**
Quercus kelloggii	**23.9**	**100**
Pinus sabiniana	6.9	100
Quercus chrysolepis	6.8	100
Aesculus californica	4.3	100
Quercus wislizeni	0.09	50
Shrub		
Toxicodendron diversilobum	**51.3**	**100**
Cercis occidentalis	6.0	100
Ceanothus integerrimus	4.3	100
Amelanchier utahensis	3.8	50
Styrax officinalis	3.8	50
Cercocarpus betuloides	2.2	50
Vitis californica	1.7	50
Heteromeles arbutifolia	1.5	50
Philadelphus lewisii	1.0	50
Holodiscus discolor	0.09	50
Polystichum munitum	0.09	50
Herb		
Torilis arvensis	1.3	100
Cynosurus echinatus	1.0	100
Galium bolanderi	0.6	50
Achnatherum occidentale	0.09	50
Aristolochia californica	0.003	100
Symphoricarpos mollis	0.002	50
Wyethia angustifolia	0.002	50

Table 23. Mean cover (percentage) and constancy for species used in analysis of *Quercus garryana* var. *breweri* shrubland alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Quegabr - Cerbet*	
	Cover	Constancy
Tree		
Quercus wislizeni	4.4	100
Pinus sabiniana	4.3	100
Quercus kelloggii	2.2	50
Quercus chrysolepis	1.7	50
Shrub		
Quercus garryana var. *breweri*	**47.9**	**100**
Cercocarpus betuloides	**8.2**	**100**
Toxicodendron diversilobum	7.4	100
Amelanchier utahensis	6.3	50
Ceanothus cuneatus	2.2	50
Quercus berberidifolia	1.7	50
Ceanothus integerrimus	1.5	100
Cercis occidentalis	0.6	50
Arctostaphylos viscida	0.5	50
Polystichum munitum	0.002	50
Herb		
Galium bolanderi	0.1	100
Symphoricarpos mollis	0.1	50
Aira caryophyllea	0.01	100
Vulpia myuros var. *myuros*	0.01	100
Torilis arvensis	0.008	100
Achnatherum occidentalis	0.007	100
Cynosurus echinatus	0.003	50
Aristolochia californica	0.002	50

454-483 m). The alliance stands are shrublands of mostly *Quercus garryana* var. *breweri* plants from 2-5 m tall; one polygon is significantly more highly vegetated than the other, with some 5-7 m tall stems of *Pinus sabiniana* emerging from an extremely dense shrub layer of *Quercus garryana* var. *breweri. Quercus wislizeni* and *Quercus chrysolepis* stems in this alliance are mostly shrubby, the same height as the *Quercus garryana* var. *breweri.*

Quercus kelloggii forest alliance

(21 polygons)

According to the definition of this forest alliance, *Quercus kelloggii* can be the sole important tree in the canopy, or it can share importance with another oak species or with *Pseudotsuga menziesii.* Regardless of whether it shares dominance, at WNRA *Quercus kelloggii* provides at least 50% relative cover within the tree cover of stands within this alliance. In the stands at WNRA where *Quercus kelloggii* shares dominance, the other important species in the tree canopy tends to be *Quercus chrysolepis.* This alliance is represented in this study by four associations and one type: the *Quercus kelloggii – Quercus chrysolepis / Heteromeles arbutifolia – Toxicodendron diversilobum* association, the *Quercus kelloggii / Toxicodendron diversilobum* association, the *Quercus kelloggii / Heteromeles arbutifolia – Toxicodendron diversilobum* association, the *Quercus kelloggii / Arctostaphylos viscida* association, and the *Quercus kelloggii – Pinus sabiniana / Styrax officinalis – Toxicodendron diversilobum* type (Table 24). The *Quercus kelloggii* forest alliance was found for the most part in locations north and west of Whiskeytown Reservoir, although the location with the *Quercus kelloggii – Pinus sabiniana / Styrax officinalis – Toxicodendron diversilobum* type was found along the southeast side of the

Table 24. Mean cover (percentage) and constancy for species used in analysis of *Quercus kelloggii* woodland alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Quekel - Pinsab / Styoff – Toxdiv*[a]	*Quekel - Quechr / Hetarb - Toxdiv*		*Quekel / Toxdiv*		*Quekel / Hetarb - Toxdiv*		*Quekel / Arcvis - Hetarb*	
	Cover	Cover	Constancy	Cover	Constancy	Cover	Constancy	Cover	Constancy
Tree									
Quercus kelloggii	**62.5**	**38.9**	**100**	**60.8**	**100**	**62.5**	**100**	**11.5**	**100**
Quercus chrysolepis	13.7	**21.8**	**100**	3	83	16.3	100	2.5	100
Pinus sabiniana	**7.7**							1.4	67
Pinus attenuata	6.7					5.5	50		
Pinus ponderosa	3.3			1.6	58	0.3	100		
Aesculus californica				1.6	50				
Pseudotsuga menziesii						0.7	50		
Calocedrus decurrens						0.6	100		
Quercus garryana						0.5	50		
Quercus wislizeni								4.8	67
Shrub									
Toxicodendron diversilobum	**40.0**	**19.6**	**100**	**36.6**	**100**	**6**	**100**	**9.6**	**100**
Styrax officinalis	**40.0**	0.7	100			0.2	50		
Cercis occidentalis	13.5	0.1	67	0.9	92	1	50		
Arctostaphylos viscida	7.7	11.9	100	4.7	67	4.8	100	**81.9**	**100**
Heteromeles arbutifolia	4.3	**34.4**	**100**	1.2	67	**10.1**	**100**	8.8	100
Pteridium aquilinum	0.007			2.2	50	0.09	50		
Polystichum munitum	0.002			1.2	58	0.09	50		
Ceanothus integerrimus				0.3	50				
Ceanothus lemmonii						1.5	50		

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Table 24. Mean cover (percentage) and constancy for species used in analysis of *Quercus kelloggii* woodland alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

Species	*Quekel - Pinsab / Styoff – Toxdiv*[a]	*Quekel - Quechr / Hetarb - Toxdiv*		*Quekel / Toxdiv*		*Quekel / Hetarb - Toxdiv*		*Quekel / Arcvis*	
	Cover	Cover	Constancy	Cover	Constancy	Cover	Constancy	Cover	Constancy
Holodiscus discolor						1.1	50		
Amelanchier utahensis						0.5	50		
Vitis californica									
Adenostoma fasciculatum								1.1	67
Herb									
Galium bolanderi	0.01	0.1	100	0.3	58	1.3	100	0.06	67
Iris sp.	0.007			0.1	58	0.005	50		
Achnatherum occidentale	0.003	0.003	100	1.3	92	0.2	100		
Symphoricarpos mollis		0.06	67	0.08	100	0.002	50		
Aristolochia californica				0.6	58	0.09	50		
Torilis arvensis				0.5	58	0.003	50		
Aira caryophyllea						0.6	50		
Vulpia myuros var. myuros						0.2	50	0.06	100
Cynosurus echinatus						0.005	100		
Apocynum androsaemifo-lium						0.002	50		
Vulpia microstachys						0.002	50		
Wyethia angustifolia						0.0009	50		

[a]No constancy value is supplied because this assemblage is a *type:* it is represented in the study by only one polygon (three relevé plots).

reservoir, just northeast of the dam, along the road that follows the shore. Several polygons were observed around the area where Clear Creek enters the lake, in draws north of the highway, on both sides of the highway where wooded areas thin out to chaparral, and west of Whiskey Gulch. It was also observed west of County Line Road, along Mill Creek Road southwest of Carr Powerhouse, and near the south shore of the reservoir to the west of Dry Creek Campground. The average elevation of the alliance was 487 m (range: 326-716 m), and slopes ranged from 15-65%. Most aspects were northwest, northeast, or east; one polygon in the *Quercus kelloggii / Arctostaphylos viscida* association faced southwest. Most of the stands in this alliance were relatively open, with cover contributed by shrubs often equal to if not greater than that contributed by trees.

Quercus wislizeni woodland alliance

(8 polygons)

This alliance is defined as having *Quercus wislizeni* alone or dominant in the tree canopy. At WNRA the stands in this alliance feature at least 75% relative cover provided by *Quercus wislizeni* in the (usually sparse) tree layer. It is represented in this study by three associations, *Quercus wislizeni / Arctostaphylos viscida, Quercus wislizeni / Toxicodendron diversilobum,* and *Quercus wislizeni / Toxicodendron diversilobum / Centaurea soltitialis* (Table 25). The first association was found at an average elevation of 415 m (range: 400-437 m) on southeasterly to southwesterly aspects. Slopes ranged from 25-50%. This association featured large *Arctostaphylos viscida* shrubs that have

Table 25. Mean cover (percentage) and constancy for species used in analysis of *Quercus wislizeni* woodland alliance. Constancy is the number of occurrences a species has in an association as a percentage of total plots.

	Quewis / Toxdiv		*Quewis / Toxdiv / Censol*		*Quewis / Arcvis*	
Species	Cover	Constancy	Cover	Constancy	Cover	Constancy
Tree						
Quercus wislizeni	**13.3**	**100**	**15**	**100**	**15.7**	**100**
Quercus chrysolepis	1.5	50				
Aesculus californica	0.5	50				
Quercus douglasii	0.1	50	0.002	50		
Quercus garryana	0.1	50				
Pinus sabiniana	.003	100			3.3	50
Shrub						
Toxicodendron diversilobum	**7.3**	**100**	**4.8**	**100**	1.8	75
Styrax officinalis	1.5	50			0.6	50
Heteromeles arbutifolia	1.3	100	0.3	100	**11.7**	**100**
Adenostoma fasciculatum	0.7	100	6	100		
Quercus berberidifolia	0.5	50	0.5	50		
Arctostaphylos viscida	0.4	100	0.006	100	**68.8**	**100**
Cercocarpus betuloides	0.2	50				
Cercis occidentalis	0.1	50				
Ceanothus prostratus			0.004	50		
Herb						
Eriodictyon californicum	1.6	100	3.8	100		
Centaurea solstitialis	1.1	100	**46.3**	**100**		
Torilis arvensis	0.8	100	0.6	100		
Vulpia myuros var. *myuros*	0.7	100	12.3	100	0.05	75
Galium bolanderi	0.2	50	0.1	100	0.2	100
Aira caryophyllea	0.1	100	2.1	100	1	75
Lotus crassifolius	0.1	50				
Cynosurus echinatus	.002	50	0.002	50		
Symphoricarpos mollis	.002	50				
Holodiscus discolor			0.09	50		
Quercus kelloggii			0.09	50		
Pseudotsuga menziesii						
Vulpia microstachys					0.2	50

been overtopped by *Quercus wislizeni.* As indicated by the names of the second and third associations, the primary difference between the two is the amount of *Centaurea solstitialis* present; in the latter association, this invasive species contributes from 22-71% cover on average. The *Quercus wislizeni / Toxicodendron diversilobum* association was found at an average elevation of 1534 m (range: 1401-1666 m) on southwest- and southeast facing slopes with gradients of 45-65%; they were located near the associations that have been invaded by *Centaurea solstitialis.* The average elevation of the *Quercus wislizeni / Toxicodendron diversilobum / Centaurea solstitialis* association was 510 m (range: 498-521 m); the association was observed on southwest aspects with slopes of 65%. The trees in this association are widely spaced and very short on average. Tree height ranges from ~1 m to ~4 m. One of the polygons in the *Quercus wislizeni / Toxicodendron diversilobum* association contained only resprouting trees of shrub height, the obvious result of a recent fire.

Ordination

NMS produced a three-dimensional ordination of polygons, which is represented as three two-dimensional ordinations here (one ordination for each combination of dimensions, Figures 2, 3, and 4). The ordination visually reveals a bimodal pattern to vegetation observations in the study; each two-dimensional ordination contains two clear clusters of polygons rather than a gradual distribution of polygons from one end of each axis to the other. Axis 1 and Axis 3 featured the same endpoints (polygons 144.1 and

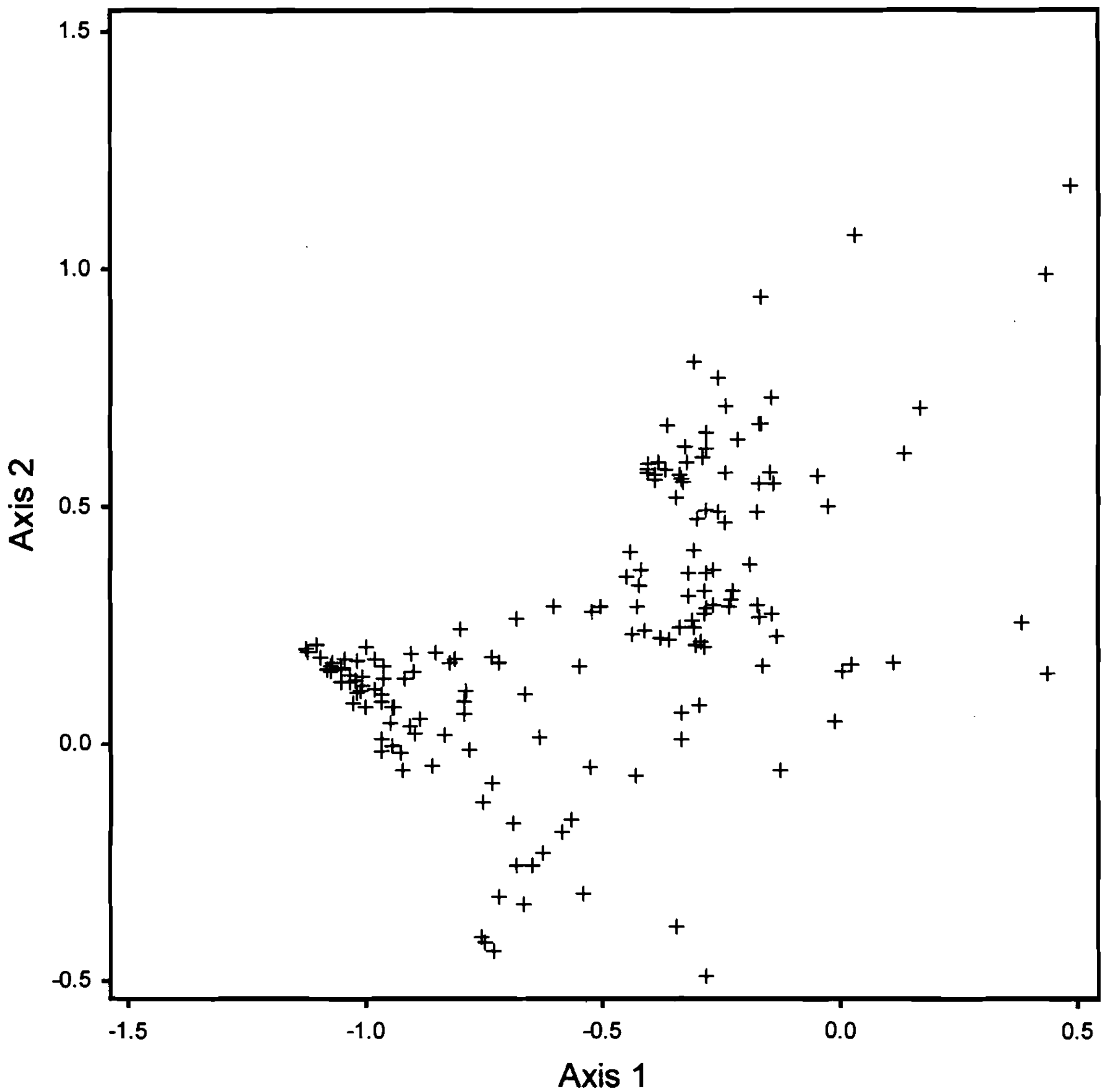

Figure 2. Nonmetric Multidimensional Scaling Ordination of vegetation polygons, showing first and second axes.

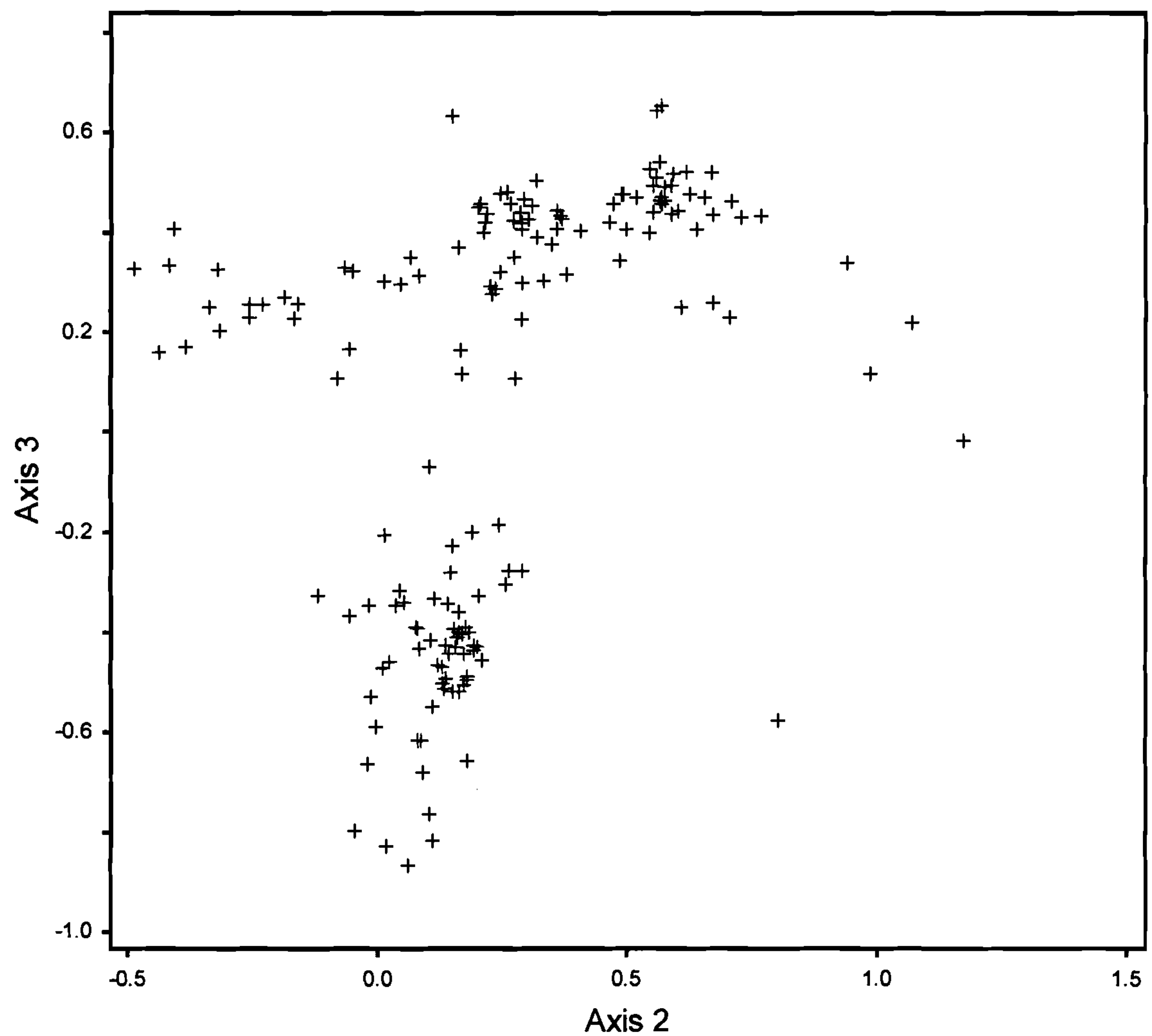

Figure 3. Nonmetric Multidimensional Scaling Ordination of vegetation polygons, showing second and third axes.

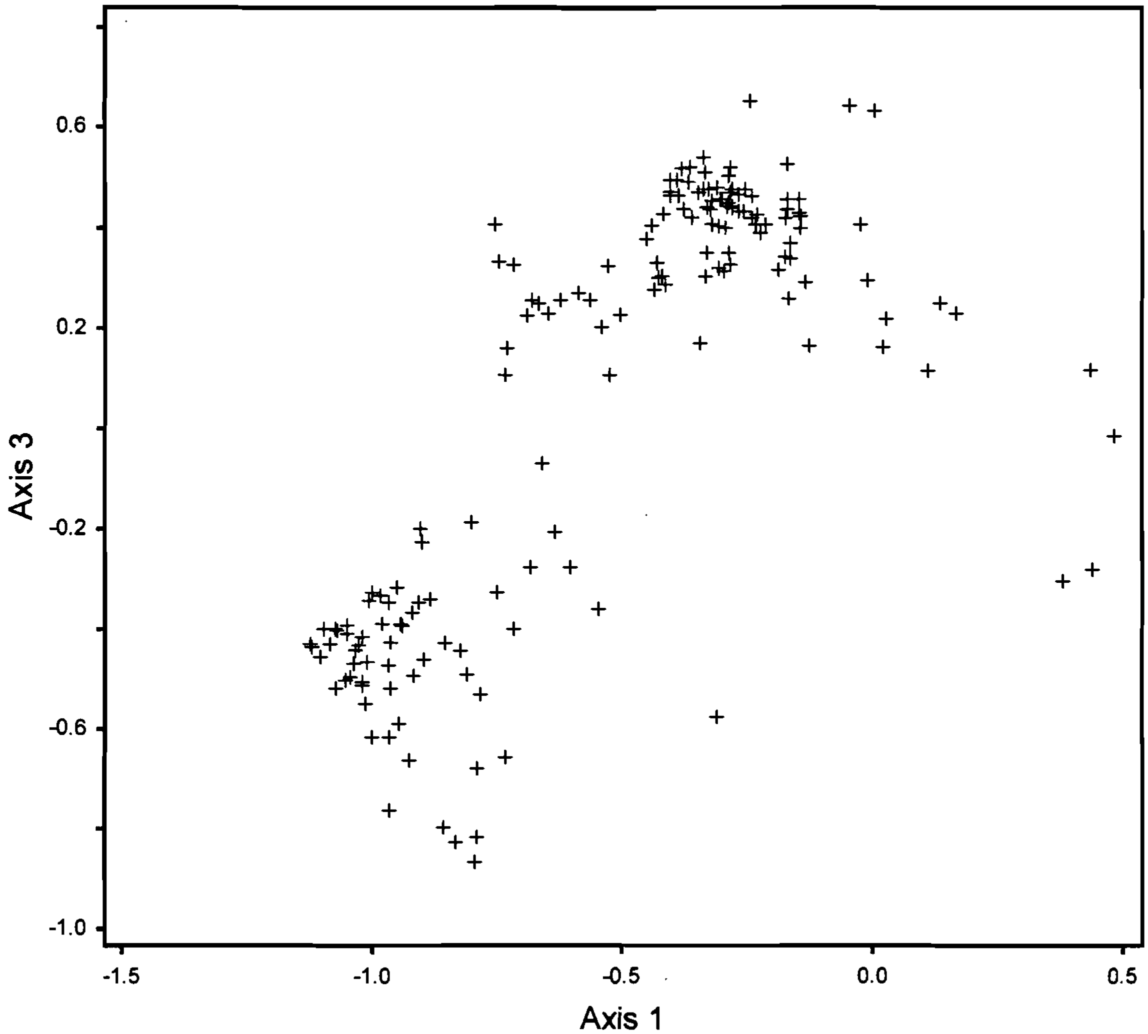

Figure 4. Nonmetric Multidimensional Scaling Ordination of vegetation polygons, showing first and third axes.

193.1), suggesting that these axes represent correlated factors. However, Axis 1 did not segregate the polygons into two distinct clusters as easily as did Axis 3.

Principal Components Analysis

PCA did not reveal clear correlations between any of the environmental variables measured in the study. On the contrary, each variable measured appeared to make a separate contribution to the analysis, as indicated by the eigenvalues associated with each variable and the scree plot associated with those eigenvalues. Had two or more variables been sufficiently correlated to combine into a "principal component" or "factor" influencing vegetation distribution and appearance, one eigenvalue and scree bar length would have been longer than the others (Table 24). Each "factor" suggested by the analysis appeared to be largely composed of one environmental variable rather than several (Figure 5). This is true for factor 6 to a lesser degree than for the others, but factor 6 contributes less to the data structure (as measured by eigenvalue) than do the others. One result that is contrary to normal expectation for this analysis concerns the moisture equivalency index (MEI) variable. Since MEI is a combination of aspect and topographic position, it already is, in a sense, a "principal component" or "factor"—a combination of two measured variables into a synthetic one that influences the independent variables observed. However, PCA did not indicate significant correlations between aspect and MEI or position and MEI and did not suggest that they be combined into a principal component.

Table 26. Factors composed of correlations between environmental variables, measured as eigenvalues. "No." refers to factor number.

Eigenvalues after Varimax Rotation				
No.	Eigenvalue	Individual Percent	Cumulative Percent	Scree Plot
1	1.03	17.12	17.12	||||
2	1.01	16.86	33.97	||||
3	1.00	16.67	50.65	||||
4	1.01	16.79	67.44	||||
5	1.00	16.65	84.08	||||
6	0.95	15.92	100.00	||||

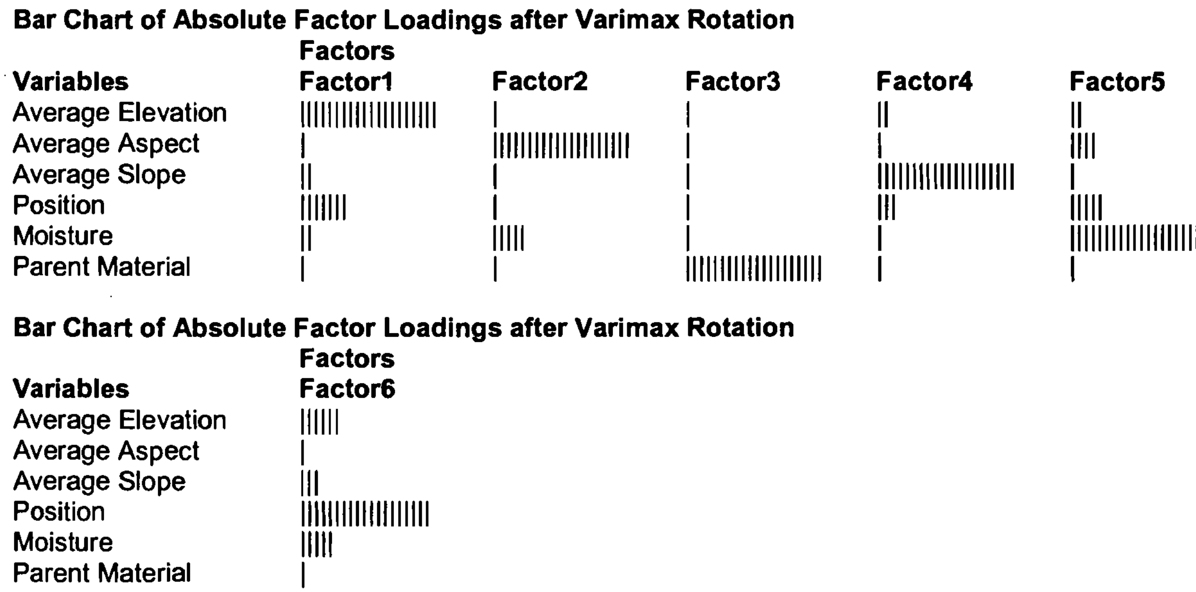

Figure 5. Composition of factors from Table 26.

Logistic Regression

The axes of the ordination represented in Figures 2, 3, and 4 were divided at values that divided the polygons into separate clusters in as equal a manner as possible. These values were arbitrary measurements that merely served to polarize the groups of polygons to provide directions of data variation. To understand the direction of variation represented by each axis, Axis 1 was divided at point –0.5 on Figure 2; Axis 2 was divided at point 0.2 on Figure 3; and Axis 3 was divided at point 0.0 on Figure 4. For each axis-by-axis representation, all polygons on one side of the division were placed into group 1 and all polygons on the other side into group 0. They were then subjected to the logistic regression algorithm in NCSS 2001 to see how well the provided variables predicted membership in one group or the other.

The program is capable of performing several logistic regression iterations while removing one variable from each iteration and measuring the accuracy of the predicted group membership each time. For Axis 1, elevation and slope were the variables that most accurately predicted group membership, with elevation providing much more discriminatory power. This can be seen by comparing the probability values for elevation and slope in Table 27; the lower the probability value and the higher the chi-square statistic, the stronger the model (Afifi and Clark 1984). Together, elevation and slope correctly classified 81.1% of the individual polygons along Axis 1. For Axis 2, Elevation and MEI provided the greatest discriminatory power (Table 28), with elevation

Table 27. Contributions of environmental variables to logistic regression model for ordination axis 1, with regression coefficients, standard errors, Chi-square statistics with probability levels, and amount added by variable to the model's coefficient of determination (R^2).

Variable	Regression Coefficient	Standard Error	Chi-Square Beta=0	Prob Level	Last R-Squared
Intercept	1.22	1.56	0.61	0.44	3.87 E-03
Average Elevation	-5.48 E-04	1.37 E-04	16.10	6.00 E-05	0.09
Average Aspect	-9.57 E-04	2.05 E-03	0.22	0.64	1.40 E-03
Average Slope	3.21 E-02	1.31 E-02	6.01	0.01	0.04
Position	1.68 E-02	0.13	0.02	0.90	1.03 E-04
Moisture (MEI)	1.66 E-02	0.10	0.03	0.87	1.71 E-04
Parent Material	6.11 E-02	0.12	0.24	0.62	1.53 E-03

Table 28. Contributions of environmental variables to logistic regression model for ordination axis 2, with regression coefficients, standard errors, Chi-square statistics with probability levels, and amount added by variable to the model's coefficient of determination (R^2).

Variable	Regression Coefficient	Standard Error	Chi-Square Beta=0	Prob Level	Last R-Squared
Intercept	3.43	2.74	1.56	0.21	0.01
Average Elevation	-2.72 E-03	5.37 E-04	25.62	0.00	0.14
Average Aspect	-3.49 E-03	4.09 E-03	0.73	0.39	4.66 E-03
Average Slope	7.11 E-03	2.69 E-02	0.07	0.79	4.49 E-04
Position	2.59 E-02	0.28	0.01	0.93	5.70 E-05
Moisture (MEI)	0.52	0.23	4.94	0.03	3.09 E-02
Parent Material	-2.16 E-02	0.14	0.02	0.88	1.50 E-04

alone correctly classifying 93.9% of the polygons. For Axis 3, MEI and elevation provided the greatest discriminatory power (Table 27), together correctly classifying 86.5% of the individual polygons along the axis; elevation again was most helpful.

Table 29. Contributions of environmental variables to logistic regression model for ordination axis 3, with regression coefficients, standard errors, Chi-square statistics with probability levels, and amount added by variable to the model's coefficient of determination (R^2).

Variable	Regression Coefficient	Standard Error	Chi-Square Beta=0	Prob Level	Last R-Squared
Intercept	3.94	1.80	4.81	0.03	0.03
Average Elevation	1.08 E-03	2.60 E-04	17.42	3.00 E-05	0.10
Average Aspect	6.97 E-04	2.83 E-03	0.06	0.81	3.89 E-04
Average Slope	2.14 E-02	1.73 E-02	1.52	0.22	9.64 E-03
Position	-0.30	0.18	2.89	0.09	0.02
Moisture (MEI)	-0.58	0.13	18.67	1.60 E-05	0.11
Parent Material	4.67 E-02	0.11	0.17	0.68	1.10 E-03

DISCUSSION

Patterns of Vegetation Distribution

The large number of separate vegetation alliances, as well as the diversity of associations within those alliances, named in this study points to a conclusion unsurprising to anyone acquainted with WNRA: the park is an area of exceptional diversity even within an area (the Klamath Region) known for its plant diversity. What is especially interesting at WNRA is that this diversity is expressed at a number of levels both within vegetation types (the generic and specific levels, also called "alpha-diversity") and between vegetation types (the alliance and association levels, also called "beta-diversity"). Whittaker (1960; 1961), Sawyer and Thornburgh (1974), Smith and Sawyer (1988), and Sawyer (2000) discuss the Klamath Region's importance as a "center" of West Coast plant diversity, a center that preserves a great deal of the remnants of the Arcto-Tertiary forests that once blanketed the West. Within the context of that conversation, WNRA can be seen as an area where vegetation types of the Pacific Northwest begin to form an interdigitating "fringe" with the vegetation types of other floristic provinces, including the Great Basin, Sierran, and Cascadian provinces. This "fringe effect" amplifies the already considerable diversity imposed by the topographic and climatic complexity, variety of parent materials, turbulent geologic history, and elevational gradients present in the rest of the Klamath Region.

The results of logistic regression used as a crude guide to clarifying the axes of ordination of the polygons in this study suggest that the elevational gradient in the park is the single most important environmental variable responsible for the patterns of vegetation distribution across the park. Obviously, elevation is complexly correlated with a number of environmental variables for which it either serves as a surrogate (such as growing temperatures) or an influence (such as wind and precipitation). This is also the case with moisture available for plant growth as estimated by the moisture equivalency index; although this index involves topographic position and aspect classes of polygons, it is not reducible to them. Principal components analysis suggests that the moisture equivalency index is not closely correlated with either of these variables. This points to the complexity of the interactions between aspect, topographic position, and moisture availability. Each of these variables most likely exerts its own influence on vegetation as well as acting together to produce synergistic or depressant effects. Each of the environmental variables measured at WNRA has a wide range of measurements, thanks to accidents of geography, geology, and historical disturbance. This enables the range of interactions between these variables to be wider than in many other areas of California.

It is relatively easy to see the broad responses of vegetation to the elevational gradient in the park, from common low-elevation chaparral including *Arctostaphylos viscida, Heteromeles arbutifolia,* and *Adenostoma fasciulatum,* to higher-elevation forests, conifer woodlands, and brushfields containing such species as *Lithocarpus densiflorus* var. *echinoides, Arctostaphylos patula,* and *Chrysolepis sempervirens.* If Axis 2 of the NMS ordination is taken to indicate the influence of elevation, the alliances fall out largely in the following manner:

Lower elevations: *Arctostaphylos viscida*
Pinus attenuata
Pinus sabiniana
Quercus douglasii
Quercus garryana var. *garryana*
Quercus garryana var. *breweri*
Quercus kelloggii
Quercus wislizeni

Middle elevations: *Pinus ponderosa*
Pinus ponderosa – Quercus kelloggii
Pseudotsuga menziesii
Pseudotsuga menziesii – Lithocarpus densiflorus
Pseudotsuga menziesii – Quercus chrysolepis
Lithocarpus densiflorus

Higher elevations: *Arctostaphylos patula*
Chrysolepis sempervirens
Lithocarpus densiflorus var. *echinoides*
Mixed conifer
Quercus berberidifolia

Ubiquitous: *Quercus chrysolepis*

If the moisture gradient is taken as a component of Axes 2 and 3 on the ordination, a pattern can also be seen for associations, although it is not as clear as the elevational pattern. The riparian associations are of course the wettest; excluding them, a spectrum of alliances can be seen from those alliances containing *Pseudotsuga menziesii* and *Lithocarpus densiflorus* var. *densiflorus* at the mesic end, through those containing *Quercus garryana, Quercus kelloggii,* and *Pinus sabiniana,* to those containing *Pinus attenuata* and *Arctostaphylos viscida,* to those containing high-elevation conifers and shrubs, to *Quercus wislizeni* and finally *Quercus berberidifolia* at the most xeric extreme. Alliances containing *Quercus chrysolepis* and *Pinus ponderosa* as major components are ubiquitous.

It bears emphasizing again that these patterns are more like hypotheses than conclusions. Ordination does not depict clear-cut environmental gradients for interpretation; its arrangement of polygons or associations in relation to each other is influenced by entire interacting complexes of such gradients. Whittaker (1960) concluded from his studies in the Siskiyou Mountains that macro- and microtopographic differences from site to site explain much variation between vegetation types in the area, because such differences are highly correlated with site moisture availability, shade/sunlight relations, and evapotranspirational stress. This seems to be true at WNRA.

Whittaker (1960) also concluded that parent material was the greatest single influence upon vegetation patterns in the Klamath Region. He recorded significant differences between vegetation patterns on serpentine, gabbro, and diorite. Given the variety of parent materials at WNRA, from sandstone to schist to granite, one would expect such a significant gradient to show up as a strong contributing element to one of the ordination axes. Yet the logistic regression results in this study indicated otherwise, removing parent material in early iterations as one of the variables least useful in discriminating between the positions of polygons on the ordination axes. There is more than one possible explanation for this. First, Whittaker's study emphasized two unusual parent materials, gabbro and serpentine, that are not represented at WNRA (although a belt of serpentine does run just west of the park). Serpentine especially represents an extremely nutrient-poor environment that is marginal for plant growth. Although it is extensive in the Klamath Region, studies that examine differences in vegetation patterns upon parent materials including ultramafic rocks in the region as a whole will inevitably find a greater difference between them than between vegetation types expressive of differences in parent material at WNRA, where the most depauperate soils are identical with the richest soils studied by Whittaker (granodiorite). In other words, differences in vegetation response are not evenly distributed across the spectrum of parent materials, and Whittaker was working with a part of that spectrum that produces extreme response.

Second, researchers have noted a marked difference between western and eastern ends of the Klamath Region (Sawyer and Thornburgh 1977; Whittaker 1960). This most likely reflects the climatic shift from maritime to continental. Whittaker, studying diorite, gabbro, and serpentine, noted that the farther east one travels, the more the vegetation growing on relatively rich parent materials (i.e., diorite) begins to resemble the vegetation growing on harsher parent materials (i.e., serpentine) toward the western end of the region. Also, beta-diversity increases from west to east across the region. He hypothesized that this could be because contrasts of moisture balance are exaggerated in xeric environments relative to mesic—a "limiting factor" idea. Elevation, the apparently most important environmental variable influencing vegetation patterns at WNRA, is related not only to moisture stress, but also to such factors as exposure to wind, percent slope, and insolation (although as mentioned before, each of these variables probably also contributes individually).

This poses difficulties for classification in the eastern part of the region, as the grain of the vegetation on a landscape scale becomes finer and finer. In this particular classification, these difficulties were most apparent in the attempt to classify the mixed conifer forests at high elevations on Shasta Bally. Little unity is apparent in these extremely varied vegetation types. They appear in some sites as almost pure *Lithocarpus densiflorus* var. *echinoides* shrublands with the occasional old conifer and a few conifer saplings emerging above the shrubs, and in other sites as nearly closed forests with over 50% cover contributed by conifers. Moreover, the mix of conifers changes from site to site, with some sites dominated primarily by *Abies concolor* and some by *Pinus ponderosa.* On some sites, *Pinus lambertiana* is nearly as abundant as the dominant conifer; on other sites it is absent or nearly so. This fine-scale variability from site to site probably indicates an active disturbance history and an ongoing successional dynamic that makes classification into associations and even alliances difficult and that calls for repeated refinements of the classification in the future.

Williams and Gaston (1994) assert that higher-taxon richness can tell us something about lower-taxon richness; for example, measuring the number of families in an area indicates something about the relative number of species in that area. This seems to be true of vegetation classification as well; the great number of alliances at WNRA betokens a similarly large number of associations. If vegetation distribution is controlled by a mix of environmental factors and disturbance events, then this large number of associations reveals a similarly large number of combinations of such factors and events. This makes re-visiting the question of gradsect sampling in a place like WNRA worthwhile, since such sampling is designed to capture as much of this variability as possible. However, such sampling only takes into account three main environmental factors (there may be more involved at WNRA). More importantly, it does not consider disturbance history. The use of subjective, image-driven stratified sampling at WNRA enables a classification that more accurately reflects that history.

Interesting and Unusual Vegetation Types

Some interesting, unusual, or hitherto undescribed vegetation types exist at WNRA. The most extensive such type comprehends the alliances that contain *Lithocarpus densiflorus* var. *echinoides* as a major component at higher elevations on Shasta Bally. Although these types were noted by Mallory and others (1973), they were mentioned exclusively as part of a conifer / shrub tanoak type. However, this species grows not only as the understory of extremely sparse conifer woodlands at WNRA, but also as nearly pure stands with some *Pteridium aquilinum* or *Arctostaphylos nevadensis*, or as part of shrublands containing other species such as *Arctostaphylos patula* and *Chrysolepis sempervirens*. No alliance has yet been described for shrublands dominated by *Lithocarpus densiflorus* var. *echinoides*.

Another interesting vegetation type comprises the associations including both *Pinus ponderosa* and *Lithocarpus densiflorus* var. *densiflorus*. The latter tree is normally described as an important element of the "Mixed Evergreen Forests" that cover much of the Klamath Region (Sawyer and others 1977), usually associated with *Pseudotsuga menziesii* and often with *Arbutus menziesii,* while the former is normally described as a component of Sierran/Cascadian/interior western forests (Franklin and Dyrness 1973). At WNRA this type is expressed both as a *Pinus ponderosa – Lithocarpus densiflorus –*

Quercus chrysolepis / Toxicodendron diversilobum type and as a *Pinus ponderosa – Lithocarpus densiflorus* association. These sites were at intermediate elevations (602 m for the type, average 975 m for the association) and relatively wet (MEI = 3 for the type, average MEI = 7.3 for the association). They were well-developed forests with little shrub or herb cover, generally on northerly or easterly slopes.

The blue oak woodland type at WNRA was found in the samples collected for this study as one type, the *Quercus douglasii / Cercis occidentalis* type. This type falls neither under the inventory of blue oak woodland types compiled by Griffin (1977) nor the one compiled by Allen-Diaz and Holzman (1991), both of which mention *Quercus douglasii* co-occurring in woodlands with *Quercus lobata, Quercus wislizeni,* or *Quercus agrifolia,* but not with *Quercus chrysolepis.* The latter oak is an important component of the type at WNRA, providing over 30% relative cover in the tree canopy.

Of other interest are the vegetation types at WNRA that are ubiquitous or seem to have wide ecological amplitudes. These are chiefly the alliances containing *Quercus chrysolepis* as the dominant tree and the complex of alliances and associations containing *Quercus kelloggii* and *Arctostaphylos viscida* as important components. *Quercus chrysolepis* is the most widely distributed tree in California (Griffin and Critchfield 1972), and this is reflected at WNRA, where alliances containing *Quercus chrysolepis* as a dominant component range from 335-1750 m in elevation, on all aspects, and grow in a variety of moisture conditions (MEI = 5 for the *Quercus chrysolepis / Toxicodendron diversilobum* association, MEI = 14 for the *Quercus chrysolepis / Arctostaphylos patula* association). *Quercus chrysolepis* is thought to be climax and ecologically stable on very steep slopes, usually of colluvial material (McDonald and Littrell 1976; Mize 1973; Stuart and others 1996; Thornburgh 1990). This is evident in some associations and communities, such as *Quercus chrysolepis / Arctostaphylos patula, Quercus chrysolepis /* rock, and *Quercus chrysolepis / Lithocarpus densiflorus* var. *echinoides,* where *Quercus chrysolepis* is the sole or overwhelmingly dominant tree on steep slopes with low moisture availability. In other associations, varying mixtures of *Quercus chrysolepis* and other trees such as *Quercus kelloggii* or *Pseudotsuga menziesii* are present. In some stands of this type, *Quercus chrysolepis* is dominant, whereas other stands feature the other trees as dominants with smaller canopy coverage contributed by *Quercus chrysolepis.* This mosaic of types could result from stand dynamics initiated in different places at different times by disturbances of varying intensity, especially by fires burning patchily over changing topography. Conifers and larger hardwoods that are slower-growing than *Quercus chrysolepis* will eventually overtop it, gradually eliminating it from the site or developing a two-tiered canopy. Thus, the *Quercus chrysolepis – Acer macrophyllum / Achnatherum occidentale* type could bear a dynamic relationship to an association such as *Pseudotsuga menziesii – Quercus chrysolepis – Acer macrophyllum / Toxicodendron diversilobum,* or the *Quercus chrysolepis – Quercus kelloggii / Toxicodendron diversilobum* association could bear such a relationship to the *Quercus kelloggii – Quercus chrysolepis / Heteromeles arbutifolia – Toxicodendron diversilobum* association.

A similar situation seems to apply to the associations and alliances containing *Arctostaphylos viscida* and *Quercus kelloggii*: large sections of WNRA are patchworks of these types in different stages of recovery from disturbance. Some stands are composed of nearly pure *Arctostaphylos viscida* with occasional seedling trees, while others contain nearly closed canopies of mature *Quercus kelloggii* with remnants of shaded-out *Arctostaphylos viscida* canopies beneath them.

Vegetation Types Not Appearing in This Study

Some vegetation types that an observer familiar with the WNRA area would expect to see represented in a vegetation classification were missing from the sampling data for this study. It is unclear whether this is because of problems with the spectral signatures used by the image-driven, unsupervised classification to stratify the samples or because the spatial extent of these types was too small to be mapped by the NVCS standard. Their exclusion from this classification points to a need for further investigation and refinement of the classification in subsequent accuracy assessment and the supervised, GIS-based classification. The types include the following:

1. Closed-canopy *Abies magnifica* forests near the summit of Shasta Bally. While *Abies magnifica* was observed during sampling as an occasional component of widely spaced conifer woodlands at high elevations, no closed-canopy forests were observed. However, other observers have documented the existence of such stands (personal communication, R.

Weatherbee, Whiskeytown National Recreation Area, P.O. Box 188, Whiskeytown, CA 96095).

2. Pure *Adenostoma fasciculatum* shrublands. *Adenostoma fasciculatum* was observed in varying admixture with *Arctostaphylos viscida* north of Highway 299, but not in pure stands, although such stands are visible on ridgetops from the highway. Park staff have advised that some of these stands are within park boundaries (personal communication, R. Weatherbee, Whiskeytown National Recreation Area, P.O. Box 188, Whiskeytown, CA 96095).

3. Halophytic perennial grass associations containing *Puccinellia howellii.* This rare grass is found just west of the reservoir close to Highway 299. Near the salt springs at this location, associations dominated by *Puccinellia howellii* are interspersed with those dominated by another grass, *Distichlis spicata.* This constitutes the only known population of *Puccinellia howellii,* which is listed by the California Native Plant Society as "rare, threatened or endangered" (Levine and others 2002). The spatial extent of the type was probably too small to be captured for sampling by the unsupervised classification.

Conclusion

The diversity of vegetation alliances and associations at WNRA is generated by many complex interactions between environmental gradients and disturbance regimes. Although elevation and moisture availability appear to be important environmental variables correlated with patterns of vegetation distribution, other variables obviously make important contributions as well, influencing each other in ways that are still largely unclear. These interactions have produced a mosaic of vegetation types, some very interesting and unusual, across the park in various states of recovery from disturbance. WNRA could be a rich source for further studies isolating the extent and effects of selected environmental variables and disturbance agents. It could also generate revealing biogeographical information about the floristic provinces for which the park serves as a crossroads and about mechanisms of plant survival, migration, and speciation in the Klamath Region as a whole. WNRA deserves respect and further study as an area of great biodiversity in general.

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APPENDIX A. Vascular plant species found in study area. Nomenclature follows *The Jepson Manual* (Hickman 1993), except that traditional family names are retained. Species the identity of which could not be resolved to the subspecific or varietal level are marked with *.

Part I. Taxa identified to species, subspecies, or variety.

ACERACEAE
- *Acer circinatum* Pursh
- *Acer glabrum* Torrey var. *torreyi* (E. Greene) F.J. Smiley
- *Acer macrophyllum* Pursh

ANACARDIACEAE
- *Rhus trilobata* Torrey & A. Gray
- *Toxicodendron diversilobum* (Torrey & A. Gray) E. Greene

APOCYNACEAE
- *Apocynum androsaemifolium* L.
- *Cycladenia humilus* Benth. var. *humilus*

ARALIACEAE
- *Aralia californica* S. Watson
- *Hedera helix* L.

ARISTOLOCHIACEAE
- *Aristolochia californica* Torrey
- *Asarum hartwegii* S. Watson

ASCLEPIADACEAE
- *Asclepias cordifolia* (Benth.) Jepson

BERBERIDACEAE
- *Berberis aquifolium* Pursh var. *repens* (Lindley) H. Scoggan

BETULACEAE
- *Alnus incana* (L.) Moench ssp. *tenuifolia* (Nutt.) Breitung
- *Alnus rhombifolia* Nutt.
- *Corylus cornuta* Marsh. var. *californica* (A. DC.) W. Sharp

BIGNONIACEAE
- *Catalpa ovata* G. Don

BLECHNACEAE
- *Woodwardia fimbriata* Smith

BORAGINACEAE
Cynoglossum grande Lehm.

CALYCANTHACEAE
Calycanthus occidentalis Hook. & Arn.

CAMPANULACEAE
Campanula prenanthoides Durand

CAPRIFOLIACEAE
Lonicera ciliosa (Pursh) Poiret
Lonicera hispidula Douglas var. *vacillans* A. Gray
Lonicera interrupta Benth.
Symphoricarpos albus (L.) S.F. Blake var. *laevigatus* (Fern.) S.F. Blake
Symphoricarpos mollis Nutt.

CARYOPHYLLACEAE
Arenaria congesta Nutt. var. *suffrutescens* (A. Gray) Robinson
Petrorhagia dubia (Raf.) G. Lopez & Romo
Saponaria officinalis L.
Silene antirrhina L.
Silene californica Durand
Stellaria media (L.) Villars

CHENOPODIACEAE
Chenopodium botrys L.

COMPOSITAE
Achillea millefolium L.
Adenocaulon bicolor Hook.
Agoseris glauca (Pursh) Raf. var. *monticola* E. Greene (Q. Jones)
Agoseris grandiflora (Nutt.) E. Greene
Antennaria argentea Benth.
Arctium lappa L.
Artemisia douglasiana Besser
Aster oregonensis (Nutt.) Cronq.
Baccharis pilularis DC.
Baccharis salicifolia (Ruíz Lopez and Pavón) Pers.
Blepharipappus scaber Hook.
Brickellia californica (Torrey & A. Gray) A. Gray
Calycadenia multiglandulosa DC.
Calycadenia truncata DC.
Centaurea solstitialis L.

Chaenactis douglasii (Hook.) Hook. & Arn. var. *douglasii*
Chrysothamnus viscidiflorus (Hook.) Nutt. var. *viscidiflorus*
Cirsium occidentale (Nutt.) Jepson var. *candidissimum* (E. Greene) J.F. Macbr.
Cirsium vulgare (Savi) Ten.
Conyza canadensis (L.) Cronq.
Ericameria bloomeri (A. Gray) J.F. Macbr.
Erigeron inornatus A. Gray var. *inornatus*
Eriophyllum lanatum (Pursh) James Forbes var. *grandiflorum* (A. Gray) Jepson
Euthamia occidentalis Nutt.
Filago gallica L.
Gnaphalium californicum DC.
Gnaphalium luteo-album L.
Grindelia camporum E. Greene
Helenium autumnale L. var. *montanum* (Nutt.) Fern.
Helenium bigelovii A. Gray
Helenium puberulum DC.
Hieracium albiflorum Hook.
Hieracium greenei A. Gray
Hypochaeris glabra L.
Hypochaeris radicata L.
Lactuca serriola L.
Lessingia nemaclada E. Greene
Madia elegans Lindley var. *densifolia* (E. Greene) Keck
Madia exigua (Smith) A. Gray
Madia gracilis (Smith) Keck
Madia minima (A. Gray) Keck
Micropus californicus Fischer & C. Meyer var. *californicus*
Microseris nutans (Hook.) Schultz-Bip.
Solidago canadensis L. ssp. *elongata* (Nutt.) Keck
Sonchus oleraceus L.
Stephanomeria exigua Nutt. ssp. *deanei* (J.F. Macbr.) Gottlieb
Stephanomeria virgata Benth. ssp. *pleurocarpa* (E. Greene) Gottlieb
Wyethia angustifolia (DC.) Nutt.
Wyethia glabra A. Gray

CONVOLVULACEAE
Calystegia occidentalis (A. Gray) Brummitt ssp. *occidentalis*
Convolvulus arvensis L.

CORNACEAE
Cornus glabrata Benth.
Cornus nuttallii Audubon
Cornus sericea L. ssp. *sericea*

Cornus sessilis Durand

CRASSULACEAE
Sedum obtusatum A. Gray*
Sedum spathulifolium Hook.

CRUCIFERAE
Arabis platysperma A. Gray var. *howellii* (S. Watson) Jepson
Barbarea orthoceras Ledeb.
Brassica tournefortii Gouan
Guillenia lasiophylla (Hook. & Arn.) E. Greene
Hirschfeldia incana (L.) Lagr.-Fossat
Streptanthus tortuosus Kellogg var. *tortuosus*

CUCURBITACEAE
Marah oreganus (Torrey & A. Gray) Howell

CUPRESSACEAE
Calocedrus decurrens (Torrey) Florin
Juniperus communis L.

CUSCUTACEAE
Cuscuta californica Hook. & Arn. var. *breviflora* Engelm.
Cuscuta subinclusa Durand & Hilg.

CYPERACEAE
Carex athrostachya Olney
Carex barbarae Dewey
Carex densa L. Bailey
Carex deweyana Schwein ssp. *leptopoda* (Mackenzie) Calder & R. Taylor
Carex feta L. Bailey
Carex geyeri Boott
Carex nudata W. Boott
Carex rossii Boott
Cyperus acuminatus Torrey & Hook.
Cyperus strigosus L.
Scirpus microcarpus C. Presl

DATISCACEAE
Datisca glomerata (C. Presl) Baillon

DENNSTAEDTIACEAE
Pteridium aquilinum (L.) Kuhn var. *pubescens* L. Underw.

DRYOPTERIDACEAE

Athyrium filix-femina (L.) Roth var. *cyclosorum* Rupr.
Dryopteris arguta (Kaulf.) Maxon
Polystichum imbricans (D. Eaton) D.H. Wagner ssp. *imbricans*
Polystichum munitum (Kaulf.) C. Presl

EQUISETACEAE

Equisetum arvense L.
Equisetum laevigatum A. Braun

ERICACEAE

Arbutus menziesii Pursh
Arctostaphylos nevadensis A. Gray
Arctostaphylos patula E. Greene
Arctostaphylos viscida C. Parry ssp. *viscida*
Chimaphila menziesii (D. Don) Sprengel
Chimaphila umbellata (L.) Bartram
Leucothoe davisiae Torrey
Pterospora andromedea Nutt.
Pyrola picta Smith
Rhododendron occidentale (Torrey & A. Gray) A. Gray
Vaccinium membranaceum Hook.

EUPHORBIACEAE

Eremocarpus setigerus (Hook.) Benth.

FAGACEAE

Chrysolepis sempervirens (Kellogg) Hjelmq.
Lithocarpus densiflorus (Hook. & Arn.) Rehder var. *densiflorus*
Lithocarpus densiflorus (Hook. & Arn.) Rehder var. *echinoides* (R. Br. Campst.)
Quercus berberidifolia Liebm.
Quercus chrysolepis Liebm.
Quercus douglasii Hook. & Arn.
Quercus garryana Hook. var. *breweri* (Engelm.) Jepson
Quercus garryana Hook. var. *garryana*
Quercus kelloggii Newb.
Quercus lobata Nee
Quercus x morehus Kellogg
Quercus vaccinifolia Kellogg
Quercus wislizeni A.DC. var. *wislizeni*

GENTIANACEAE

Centaurium venustum (A. Gray) Robinson
Swertia albicaulis (Griseb.) Kuntze

GRAMINEAE

Achnatherum occidentale (Thurber) Barkworth*
Aegilops triuncialis L.
Agrostis exarata Trin.
Agrostis idahoensis Nash
Aira caryophyllea L.
Alopecurus pratensis L.
Avena barbata Link
Avena fatua L.
Briza maxima L.
Briza minor L.
Bromus briziformis Fischer & C. Meyer
Bromus ciliatus L.
Bromus diandrus Roth
Bromus hordeaceus L.
Bromus inermis Leysser ssp. *inermis*
Bromus madritensis L. ssp. *rubens* (L.) Husnot
Bromus sterilis L.
Bromus tectorum L.
Cynosurus echinatus L.
Dactylis glomerata L.
Deschampsia cespitosa (L.) Beauv. ssp. *cespitosa*
Deschampsia danthonioides (Trin.) Munro
Deschampsia elongata (Hook.) Munro
Digitaria ischaemum (Schreber) Meuhlenb.
Digitaria sanguinalis (L.) Scop.
Echinocloa crus-galli (L.) P. Beauv.
Elymus elymoides (Raf.) Swezey ssp. *californicus* (J.G. Smith) Barkworth
Elymus glaucus Buckley ssp. *glaucus*
Elymus multisetus (J.G. Smith) Burtt Davy
Elymus stebbinsii Gould
Eragrostis mexicana (Hornem.) Link
Festuca occidentalis Hook.
Festuca pratensis Hudson
Gastridium ventricosum (Gouan) Schinz & Thell.
Holcus lanatus L.
Koeleria macrantha (Ledeb.) J.A. Schultes
Lolium multiflorum Lam.
Lolium perenne L.
Melica harfordii Bolander
Panicum acuminatum Sw. var. *acuminatum*
Panicum acuminatum Sw. var. *lindheimeri* (Nash) Beetle
Panicum capillare L.

Phleum pratense L.
Poa bulbosa L.
Poa compressa L.
Polypogon australis Brongn.
Polypogon maritimus Willd.
Secale cereale L.
Taeniatherum caput-medusae (L.) Nevski
Vulpia microstachys (Nutt.) Munro var. *ciliata* (Beal) Lonard & Gould
Vulpia myuros (L.) C. Gmelin var. *hirsuta* Hack.
Vulpia myuros (L.) C. Gmelin var. *myuros*

GROSSULARIACEAE
Ribes lobbii A. Gray
Ribes nevadense Kellogg
Ribes roezlii Regel*
Ribes viscosissimum Pursh

HIPPOCASTANACEAE
Aesculus californica (Spach) Nutt.

HYDROPHYLLACEAE
Eriodictyon californicum (Hook. & Arn.) Torrey
Nemophila parviflora Benth.*
Phacelia corymbosa Jepson

HYPERICACEAE
Hypericum concinnum Benth.
Hypericum perforatum L.

IRIDACEAE
Iris tenuissima Dykes

JUGLANDACEAE
Juglans nigra L.

JUNCACEAE
Juncus bufonius L. var. *occidentalis* F.J. Herm.
Juncus covillei Piper var. *obtusatus* (Engelm.) C. Hitchc.
Juncus effusus L. var. *pacificus* Fern. & Wieg.
Juncus ensifolius Wikström
Juncus oxymeris Engelm.
Juncus tenuis Willd.
Juncus xiphioides E. Meyer
Luzula comosa E. Meyer

LABIATAE

Marrubium vulgare L.
Mentha arvensis L.
Monardella odoratissima Benth.
Prunella vulgaris L. var. *lanceolata* (Barton) Fern.
Pycnanthemum californicum Torrey
Salvia sonomensis E. Greene
Scutellaria siphocampyloides Vatke
Stachys ajugoides Benth. var. *ajugoides*

LEGUMINOSAE

Cercis occidentalis Torrey
Cytisus scoparius (L.) Link
Genista monspessulana (L.) L. Johnson
Glycyrrhiza lepidota Pursh
Lathryus latifolius L.
Lathyrus sulphureus A. Gray
Lotus corniculatus L.
Lotus crassifolius (Benth.) E. Greene var. *crassifolius*
Lotus grandiflorus (Benth.) E. Greene var. *grandiflorus*
Lotus humistratus E. Greene
Lotus micranthus Benth.
Lotus oblongifolius (Benth.) E. Greene var. *oblongifolius*
Lotus pinnatus Hook.
Lotus purshianus (Benth.) Clements & E.G. Clements var. *purshianus*
Lupinus albifrons Benth. var. *albifrons*
Lupinus bicolor Lindley
Lupinus latifolius J. Agardh var. *latifolius*
Melilotus alba Medikus
Pickeringia montana Nutt. var. *montana*
Robinia pseudoacacia L.
Thermopsis macrophylla Hook. & Arn. var. *venosa* (Eastw.) Isely
Trifolium hirtum All.
Trifolium monanthum A. Gray var. *monanthum*
Trifolium obtusiflorum Hook. & Arn.
Trifolium variegatum Nutt.
Vicia americana Willd. var. *americana*
Vicia sativa L. ssp. *nigra* (L.) Erhart

LILIACEAE

Allium amplectens Torrey
Allium campanulatum S. Watson
Allium obtusum Lemmon var. *obtusum*

Allium parvum Kellogg
Calochortus tolmiei Hook. & Arn.
Chlorogalum ponderidianum (DC.) Kunth var. *pomeridianum*
Dichelostemma ida-maia (A.W. Wood) E. Greene
Disporum hookeri (Torrey) Nicholson
Lilium pardalinum Kellogg*
Odontostomum hartwegii Torrey
Smilacina racemosa (L.) Link
Smilacina stellata (L.) Desf.
Smilax californica (A. DC.) A. Gray
Xerophyllum tenax (Pursh) Nutt.

OLEACEAE
Fraxinus latifolia Benth.

ONAGRACEAE
Epilobium angustifolium L. ssp. *circumvagum* Mosq.
Epilobium brachycarpum C. Presl
Epilobium canum (E. Greene) Raven ssp. *latifolium* (Hook.) Raven
Epilobium ciliatum Raf.*
Epilobium densiflorum (Lindley) P. Hoch & Raven
Epilobium glaberrimum Barbey*
Gayophytum diffusum Torrey & A. Gray ssp. *parviflorum* Harlan Lewis & J. Szweykowski
Gayophytum humile A.L. Juss.

ORCHIDACEAE
Cephalanthera austiniae (A. Gray) A.A. Heller
Piperia elegans (Lindley) Rydb.
Platanthera leucostachys Lindley
Spiranthes romanzoffiana Cham.

OROBANCHACEAE
Boschniakia strobilacea A. Gray
Orobanche fasciculata Nutt.

PAPAVERACEAE
Dicentra formosa (Haw.) Walp.

PHILADELPHACEAE
Philadelphus lewisii Pursh

PINACEAE

Abies concolor (Gordon & Glend.) Lindley
Abies magnifica Andr. Murray var. *shastensis* Lemmon
Pinus attenuata Lemmon
Pinus lambertiana Douglas
Pinus ponderosa Laws.
Pinus sabiniana Douglas
Pseudotsuga menziesii (Mirbel) Franco

PLANTAGINACEAE

Plantago coronupus L.
Plantago erecta E. Morris
Plantago lanceolata L.
Plantago major L.

POLEMONIACEAE

Collomia grandiflora Lindley
Collomia heterophylla Hook.
Gilia capitata Sims ssp. *capitata*
Linanthus ciliatus (Benth.) E. Greene
Navarretia intertexta (Benth.) Hook. ssp. *intertexta*

POLYGALACEAE

Polygala cornuta Kellogg var. *cornuta*

POLYGONACEAE

Eriogonum lobbii Torrey & A. Gray var. *lobbii*
Eriogonum nudum Benth. var. *pubiflorum* Benth.
Eriogonum vimineum Benth.
Polygonum californicum Meissner
Polygonum lapathifolium L.
Rumex acetosella L.
Rumex crispus L.
Rumex salicifolius J.A. Weinm.*

PORTULACACEAE

Claytonia rubra (Howell) Tidestrom ssp. *rubra*
Montia parvifolia (DC.) E. Greene

PRIMULACEAE

Trientalis latifolia Hook.

PTERIDACEAE

Adiantum capillus-veneris L.
Aspidotis densa (Brackenr.) Lellinger
Cheilanthes gracillima D. Eaton
Pentagramma triangularis (Kaulf.) G. Yatskievych, M.D. Windham & E. Wollenweber ssp. *triangularis*

RANUNCULACEAE

Aquilegia formosa Fischer
Clematis lasiantha Nutt.
Clematis ligusticifolia Nutt.
Delphinium decorum Fischer & C. Meyer ssp. *tracyi* Ewan
Delphinium nudicaule Torrey & A. Gray
Ranunculus californicus Benth.
Ranunculus occidentalis Nutt.

RHAMNACEAE

Ceanothus cuneatus (Hook.) Nutt. var. *cuneatus*
Ceanothus integerrimus Hook. & Arn.
Ceanothus lemmonii C. Parry
Ceanothus prostratus Benth.
Rhamnus californica Eschsch.*
Rhamnus ilicifolia Kellogg
Rhamnus purshiana DC. var. *annonifolia* (E. Greene) Jepson
Rhamnus rubra E. Greene
Rhamnus tomentella Benth. ssp. *crassifolia* (Jepson) J.O. Sawyer
Rhamnus tomentella Benth. spp. *tomentella*

ROSACEAE

Adenostoma fasciculatum Hook. & Arn.
Amelanchier utahensis Koehne
Aruncus dioicus Walter (Fern.) var. *pubescens* (Rydb.) Fern.
Cercocarpus betuloides Torrey & A. Gray var. *betuloides*
Crataegus suksdorfii (Sarg.) Kruschke
Geum triflorum Pursh
Heteromeles arbutifolia (Lindley) Roemer
Holodiscus discolor (Pursh) Maxim.
Malus fusca (Raf.) C. Schneider
Potentilla glandulosa Lindley*
Potentilla gracilis Hook. var. *fastigiata* (Nutt.) S. Watson
Prunus subcordata Benth.
Prunus virginiana L. var. *demissa*
Rosa californica Cham. & Schldl.
Rosa gymnocarpa Nutt.

Rosa spithamea S. Watson
Rubus discolor Weihe & Nees
Rubus leucodermis Torrey & A. Gray
Rubus parviflorus Nutt.
Rubus ursinus Cham. & Schldl.
Spiraea douglasii Hook.

RUBIACEAE
Cephalanthus occidentalis L. var. *californicus* Benth.
Crucianella angustifolia L.
Galium aparine L.
Galium bolanderi A. Gray
Galium grayanum Ehrend. var. *grayanum*
Galium parisiense L.
Galium triflorum Michaux
Kelloggia galioides Torrey

SALICACEAE
Populus balsamifera L. ssp. *trichocarpa* (Torrey & A. Gray) Brayshaw
Populus fremontii S. Watson ssp. *fremontii*
Salix exigua Nutt.
Salix laevigata Bebb
Salix lasiolepis Benth.
Salix melanopsis Nutt.
Salix scouleriana Hook.

SANTALACEAE
Comandra umbellata (L.) Nutt. ssp. *californica* (Rydb.) Piehl

SAXIFRAGACEAE
Darmera peltata (Torrey) Voss
Tellima grandiflora (Pursh) Lindley

SCROPHULARIACEAE
Castilleja applegatei Fern.
Cordylanthus tenuis A. Gray ssp. *viscidus* (Howell) Chuang & Heckard
Keckiella breviflora (Lindley) Straw var. *glabrisepala* (Keck) N. Holmgren
Keckiella corymbosa (Benth.) Straw
Keckiella lemmonii (A. Gray) Straw
Kickxia elatine (L.) Dumort.
Mimulus aurantiacus Curtis
Mimulus cardinalis Benth.
Mimulus floribundus Lindley
Mimulus guttatus DC.

Mimulus moschatus Lindley
Mimulus pulsiferae A. Gray
Mimulus tilingii Regel
Pedicularis densiflora Hook.
Penstemon azureus Benth. var. *azureus*
Penstemon newberryi A. Gray var. *berryi* (Eastw.) N. Holmgren
Verbascum blattaria L.
Verbascum thapsus L.

SIMAROUBACEAE
Ailanthus altissima (Miller) Swingle

SOLANACEAE
Solanum parishii A.A. Heller

STYRACACEAE
Styrax officinalis L. var. *redivivus* (Torrey) H. Howard

TAXACEAE
Taxus brevifolia Nutt.

TYPHACEAE
Typha angustifolia L.

UMBELLIFERAE
Angelica arguta Nutt.
Anthriscus caucalis M. Bieb.
Daucus pusillus Michaux
Lomatium dissectum (Torrey & A. Gray) Mathias & Constance*
Lomatium macrocarpum (Torrey & A. Gray) J. Coulter & Rose
Lomatium utriculatum (Torrey & A. Gray) J. Coulter & Rose
Osmorhiza chilensis Hook. & Arn.
Perideridia kelloggii (A. Gray) Mathias
Sanicula bipinnatifida Hook.
Sanicula graveolens DC.
Sanicula tracyi Shan & Constance
Torilis arvensis (Hudson) Link
Torilis nodosa (L.) Gaertner
Yabea microcarpa (Hook. & Arn.)

VIOLACEAE
Viola lobata Benth. ssp. *integrifolia* (S. Watson) R.J. Little
Viola purpurea Kellogg*

VISCACEAE

Arceuthobium californicum Hawksw. & Wiens
Arceuthobium campylopodum Engelm.
Phoradendron villosum (Nutt.) Nutt.

VITACEAE

Vitis californica Benth.

Part II. Taxa identified to genus.

BORAGINACEAE

Cryptantha

CARYOPHYLLACEAE

Minuartia

CYPERACEAE

Eleocharis

LILIACEAE

Brodiaea

POACEAE

Hordeum

SAXIFRAGACEAE

Heuchera

APPENDIX B. Spectral class polygon centroid locations with area, elevation, aspect, and 1:9000 locator map number for upland polygons, followed by indicator map. Datum: UTM Zone 10 NAD83.

Polygon #	Polygon Area (ha)	Elevation (m)	Aspect (azimuth)	Easting (m)	Northing (m)	Locator Map
1--1	0.72	386	335	532082	4499474	WH6
1--2	0.63	525	226	528084	4500585	FG4
1--3	0.61	400	287	539912	4495085	IG10
2--1	11.27	334	125	538262	4493467	IG9
2--2	10.96	332	206	540347	4492005	IG13, 14
2--3	10.94	393	213	537812	4500428	WH4
3--1	5.56	1486	127	524574	4496166	SB1
3--2	14.67	493	122	530499	4502893	FG2
3--3	9.86	1318	107	525024	4495445	SB1
4--1	0.68	980	94	532269	4494800	IG6
4--2	1.01	960	95	532359	4495004	IG6
4--3	0.77	634	138	534564	4493504	IG7
5--1	2.12	701	138	540392	4498997	WH11
5--2	3.35	1866	206	529352	4494483	SB7
5--3	1.33	1235	95	525827	4495004	SB5
6--1	0.45	534	219	539664	4499055	WH10
6--2	0.43	411	172	540197	4496924	IG5
6--3	0.43	512	119	539372	4498925	WH10
7--1	0.74	397	186	533162	4499901	IG10
7--2	0.70	387	241	539244	4494727	WH2
7--3	0.86	412	199	538074	4497789	WH9
8--1	1.10	1622	79	529734	4495463	SB3
8--2	0.88	1661	108	530379	4494860	SB8
8--3	0.59	1276	98	531849	4494584	IG6
9--1	0.63	879	113	540204	4499980	WH5
9--2	0.52	466	55	531062	4501134	FG5
9--3	0.95	347	92	539567	4490742	IG16
10--1	1.10	728	69	528909	4498742	FG7
10--2	0.88	686	70	527642	4499217	FG6
10--3	0.83	573	95	533222	4500824	WH2
11--1	0.52	697	290	540332	4499075	WH11
11--2	0.70	432	199	535292	4500509	WH3
11--3	0.50	365	203	539057	4493082	IG13
12--1	1.17	381	56	535397	4496919	IG3
12--2	1.04	318	204	538802	4492590	IG13
12--3	0.88	453	345	530904	4501117	FG5
13--1	0.74	659	264	540054	4498125	WH11
13--2	0.65	1372	288	527064	4493775	SB6
13--3	0.56	813	232	526779	4498145	FG6

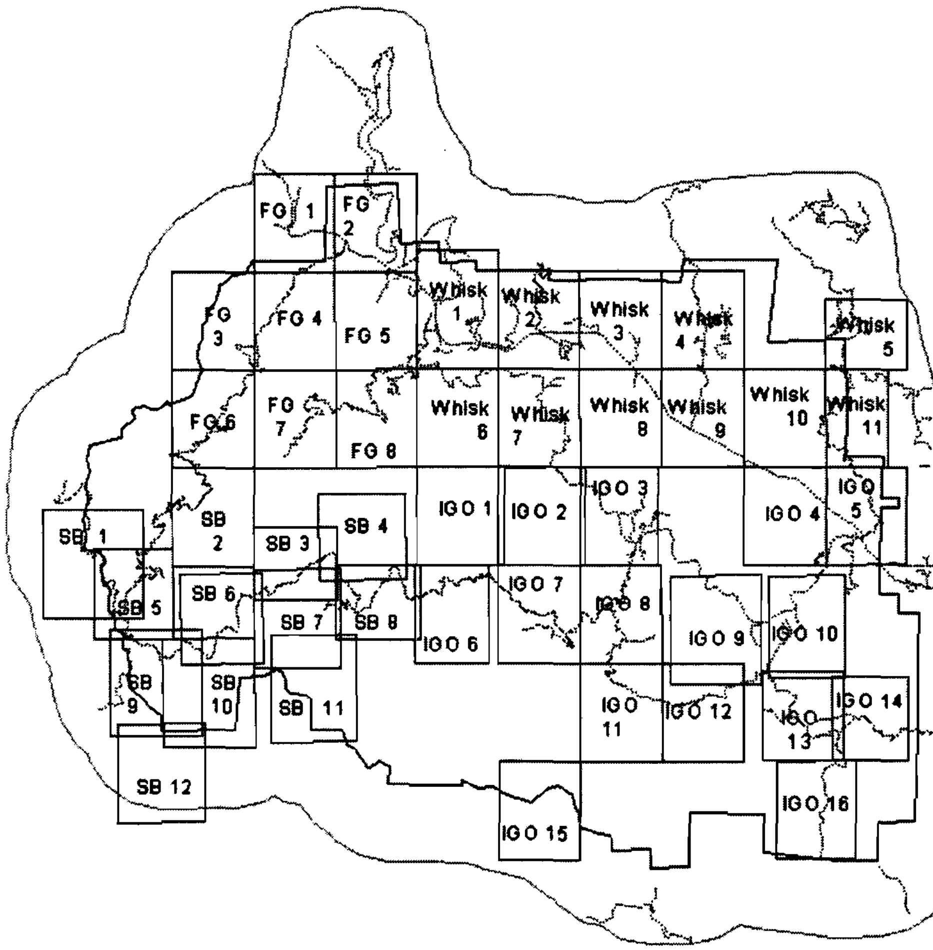
Polygon #	Polygon Area (ha)	Elevation (m)	Aspect (azimuth)	Easting (m)	Northing (m)	Locator Map
14--1	5.29	401	128	533514	4500172	WH2
14--2	11.95	1410	109	524687	4495899	SB1
14--3	5.83	325	221	539934	4492138	IG13
15--1	0.50	676	196	540174	4499320	WH11
15--2	0.45	580	205	540647	4497385	IG5
15--3	0.52	497	157	540879	4497220	IG5
16--1	4.37	374	212	537819	4499765	WH4
16--2	1.55	1860	95	529599	4494729	SB7
16--3	1.31	1496	130	524514	4496161	SB1
17--1	0.99	412	105	537092	4500940	WH4
17--2	0.52	404	86	531557	4500910	WH1
17--3	0.52	413	91	534549	4497036	IG2
21--1	0.45	417	184	539312	4497428	IG4, WH10
21--2	0.45	409	207	540324	4496487	IG5
21--3	0.41	461	111	541029	4496665	IG5
28--1	1.22	407	182	529892	4502188	FG2
28--2	1.55	391	130	534497	4500044	WH2
28--3	1.53	370	26	536192	4496739	IG3
34--1	1.91	423	63	530529	4501473	FG5
34--2	0.63	448	47	529614	4502178	FG1
34--3	0.61	626	25	530297	4498602	FG8
35--1	0.54	506	341	532209	4500910	WH1
35--2	0.50	473	331	532127	4500950	WH1
35--3	0.41	479	30	533274	4499235	WH7
55--1	0.79	322	115	539529	4490240	IG16
55--2	0.68	533	211	530154	4502237	FG2
55--3	0.68	296	87	539582	4489492	IG16
58--1	1.91	391	193	536042	4499448	WH3, 8
58--2	2.09	371	147	537152	4498229	WH9
58--3	1.67	392	209	538239	4497631	WH9
64--1	1.33	604	219	528249	4499158	FG7
64--2	1.71	431	204	531437	4499272	WH6
64--3	1.76	544	137	535869	4494149	IG8
86--1	0.59	524	85	528354	4500834	FG4
86--2	0.54	1834	83	529682	4494417	SB7
86--3	0.92	714	89	527207	4499922	FG3
124--1	2.72	1398	295	526359	4493348	SB9, 10
124--2	3.29	1543	317	527312	4493333	SB10
124--3	2.14	1369	94	526202	4493252	SB9
132--1	1.06	1336	332	528062	4495012	SB6
132--2	1.42	1448	294	528369	4494989	SB7
132--3	0.92	1412	286	528099	4494704	SB7

Polygon #	Polygon Area (ha)	Elevation (m)	Aspect (azimuth)	Easting (m)	Northing (m)	Locator Map
135--1	1.10	1340	307	528017	4494974	SB6
135--2	1.58	1609	287	528609	4494849	SB7
135--3	0.56	562	29	530049	4503065	FG2
139--1	0.97	1360	294	528017	4494865	SB6
139--2	0.74	1531	85	530874	4494885	SB8
139--3	0.72	1314	70	531339	4495272	SB4, 8
144--1	0.54	1764	97	529869	4494386	SB8
144--2	1.19	1683	77	529637	4495442	SB3
144--3	2.45	1716	106	530072	4494253	SB8
145--1	0.54	660	125	529202	4498953	FG7
145--2	1.17	1511	79	529839	4495662	SB4
145--3	0.52	1831	158	529292	4494380	SB7
147--1	2.86	1735	73	529644	4495165	SB7
147--2	1.40	1793	76	529809	4494679	SB8
147--3	2.27	1732	75	525669	4491043	SB8
148--1	1.26	561	68	527994	4500549	FG3
148--2	1.24	680	136	527514	4499003	FG3
148--3	1.24	506	55	530259	4503037	FG2
156--1	0.52	1316	159	525452	4493095	SB9
156--2	0.61	1789	275	529449	4495299	SB3
156--3	0.50	1556	308	528482	4494700	SB7
158--1	0.70	1593	325	529569	4495779	SB3
158--2	0.56	1634	85	530574	4494645	SB8
158--3	0.56	1678	75	530372	4494620	SB8
166--1	0.27	1406	114	531099	4495130	SB4, SB8
166--2	0.36	1432	201	527027	4492827	SB10
166--3	0.27	1362	30	529262	4493086	SB11
169--1	0.54	1797	296	529509	4494330	SB7
169--2	0.61	1494	295	526629	4493497	SB6, 10
169--3	0.54	1506	75	529787	4495985	SB3
174--1	0.47	1572	137	530507	4494378	SB8
174--2	0.45	1741	185	529787	4494110	SB8
174--3	0.45	1794	169	529157	4494261	SB7
176--1	1.17	1763	92	529899	4494557	SB8
176--2	0.65	1719	71	529997	4494645	SB8
176--3	0.50	1837	107	529704	4494554	SB7
177--1	1.22	1510	104	529839	4495710	SB4
177--2	0.77	1617	77	529772	4495335	SB4, 8
177--3	0.61	1573	130	530529	4494415	SB8
181--1	4.57	1520	305	528872	4495421	SB3
181--2	3.76	1754	313	529344	4495267	SB7
181--3	3.17	355	232	539604	4492784	IG13

Polygon #	Polygon Area (ha)	Elevation (m)	Aspect (azimuth)	Easting (m)	Northing (m)	Locator Map
182--1	0.86	569	239	531984	4501627	WH1
182--2	1.62	446	272	534249	4500739	WH2
182--3	1.33	466	244	532052	4500750	WH1
184--1	1.40	546	221	532764	4501196	WH1, FG3
184--2	1.19	628	135	527492	4500209	FG3, 4
184--3	1.33	439	205	538329	4497769	WH9, 10
185--1	0.43	499	315	533882	4498160	WH7
185--2	0.38	478	331	533882	4498263	WH7
185--3	0.29	356	165	540062	4489983	IG16
192--1	0.54	545	322	532232	4500846	WH1
192--2	0.50	448	323	532074	4500989	WH1
192--3	0.72	422	306	530252	4501692	FG2, 5
193--1	3.33	462	97	530394	4501593	FG5
193--2	0.99	422	64	534759	4496905	IG2
193--3	0.88	394	82	537137	4501032	WH4
194--1	0.74	422	118	538817	4491735	IG13
194--2	0.50	307	81	539507	4489827	IG16
194--3	0.47	512	236	530094	4502255	FG2
196--1	0.52	458	79	533454	4499262	WH7
196--2	0.68	584	78	535877	4492565	IG11
196--3	0.52	339	53	539552	4490840	IG16
199--1	1.37	487	176	530207	4502129	FG2
199--2	1.40	317	115	539597	4490278	IG16
199--3	0.50	296	100	539724	4490525	IG16
203--1	0.45	658	296	540204	4498865	WH11
203--2	0.43	423	167	537009	4498450	WH9
203--3	0.56	477	260	540542	4497177	IG5
206--1	0.99	931	66	532389	4494770	IG6
206--2	0.68	624	116	534152	4493909	IG7
206--3	0.61	683	124	533829	4493860	IG7
207--1	0.77	967	92	532367	4494656	IG6
207--2	0.77	708	315	533267	4494965	IG7
207--3	0.59	877	97	532562	4494860	IG6
209--1	0.63	472	221	541442	4492317	IG14
209--2	0.79	558	243	531894	4501710	WH1
209--3	0.54	445	251	541389	4492125	IG14
210--1	3.58	1480	299	528797	4495451	SB3
210--2	2.52	950	242	526487	4496982	SB2
210--3	2.50	610	296	535337	4494203	IG8
214--1	0.32	1314	51	529457	4492420	SB11
214--2	0.32	1106	67	534444	4491055	IG15
214--3	0.29	1524	91	528107	4493360	SB7

Polygon #	Polygon Area (ha)	Elevation (m)	Aspect (azimuth)	Easting (m)	Northing (m)	Locator Map
216--1	1.15	1617	331	529382	4495605	SB3
216--2	0.95	1317	302	527822	4494757	SB6
216--3	0.86	1472	206	528257	4494690	SB7
217--1	0.79	1678	234	530297	4494764	SB8
217--2	0.45	1454	60	531069	4494705	SB8
217--3	0.41	1561	40	530597	4495055	SB8
219--1	0.79	1404	294	528174	4494899	SB7
219--2	0.86	1684	221	529952	4494879	SB8
219--3	0.56	1513	77	530934	4494771	SB8

Index Key to 1:9000 Scale maps for Whiskeytown NRA Vegetation Sampling



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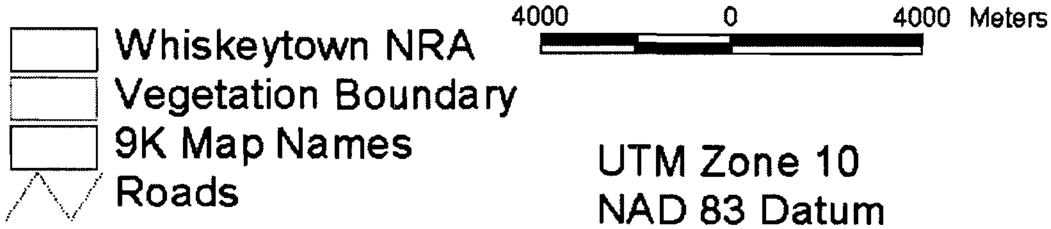

UTM Zone 10
NAD 83 Datum

APPENDIX C. Riparian sampling site centroid locations with elevation, aspect, and 1:9000 locator map number. Datum: UTM Zone 10 NAD83.

Creek Name	Sampling site	Elevation (m)	Aspect (azimuth)	Easting (m)	Northing (m)	Locator Map
Lower Clear	LC1	289	318	538960	4493918	IG10
	LC2	289	281	537995	4492861	IG12
	LC3	281	83	539041	4492188	IG13
	LC4	270	251	539602	4491338	IG16
	LC5	260	324	539676	4489471	IG16
Southern Boulder	B1	289	352	538658	4492384	IG13
	B2	413	200	537196	4491740	IG12
Brandy	BR1	410	293	535798	4495511	IG3
	BR2	486	299	535150	4494653	IG8
	BR3	608	151	533645	4494091	IG7
	BR4	801	79	532087	4493520	IG6
	BR5	1211	95	529597	4493137	SB11
Crystal	C1	480	10	528170	4500380	FG3, 4
	C2	654	243	527565	4498759	FG6
	C3	925	1	526874	4496515	SB2
	C4	1140	347	525905	4494278	SB5
	C5	1398	301	527656	4494045	SB6
Northern Boulder	BO1	402	54	533955	4498902	WH7
	BO2	685	299	531510	4497458	IG1
	BO3	1214	340	530354	4495790	SB4
Mill	M1	407	8	530556	4500890	FG5
	M2	623	352	529642	4498591	FG7, 8
Upper Clear	UC1	387	315	530889	4501616	FG2, 5
	UC2	400	222	531021	4503242	FG2
Willow	W1	434	328	529013	4502236	FG1
Whiskey Gulch	WG1	386	288	537203	4500956	WH4
Grizzly Gulch	G1	385	264	533863	4500880	WH2
	G2	431	281	533834	4501543	WH2

APPENDIX D. Field Key to Vegetation Associations and Communities of Whiskeytown National Recreation Area.

1. Shrub tanoak *and/or* bush chinquapin is present; the plot is upland

2. Shrub tanoak provides <50% relative cover within the shrub layer, generally <<50%

3. Scrub oak provides >60% relative cover within the shrub layer .... **Scrub oak – greenleaf manzanita type**

3' Scrub oak provides <5% relative cover within the shrub layer

4. Canyon live oak provides >75% relative cover within the tree layer

5. Shrub layer provides <10% total cover of plot .... **Canyon live oak / rock association**

5' Shrub layer provides >20% total cover of plot .... **Canyon live oak / greenleaf manzanita association**

4' Canyon live oak provides <10% relative cover within the tree layer

6. Pinemat manzanita provides 30% or greater relative cover within the shrub layer .... **Greenleaf manzanita – bush chinquapin / pinemat manzanita association**

6' Pinemat manzanita provides <10% relative cover within the shrub layer

7. Bush chinquapin provides more cover within the shrub layer than does shrub tanoak .... **Ponderosa pine – white fir / greenleaf manzanita – bush chinquapin type**

7' Shrub tanoak provides more cover within the shrub layer than does bush chinquapin .... **Ponderosa pine – sugar pine/ greenleaf manzanita – shrub tanoak association**

2' Shrub tanoak provides >50% relative cover within the shrub layer

8. Trees provide at least 10% of total plot cover

9. Canyon live oak provides 75% or greater relative cover within the tree layer .... **Canyon live oak / shrub tanoak association**

9' Canyon live oak provides <10% relative cover within the tree layer

10. Ponderosa pine is the sole significant tree (>75% relative cover in the tree layer) .... **Ponderosa pine / shrub tanoak association**

10' Ponderosa pine is present, but other trees are significant (>30% relative cover in the tree layer)

11. White fir is significant (>20% relative cover in the tree layer)

12. White fir is more abundant in tree layer than ponderosa pine .... **White fir – sugar pine - ponderosa pine / shrub tanoak association**

12' Ponderosa pine is more abundant in tree layer than white fir

13. Sugar pine is present and contributes at least 5% relative cover .... **Ponderosa pine – sugar pine / shrub tanoak association**

13' Sugar pine is absent or present only as scattered seedlings .... **Ponderosa pine – white fir / shrub tanoak association**

11' White fir is not significant (<10% relative cover in the tree layer) .... **Ponderosa pine – sugar pine / shrub tanoak association**

8' Trees do not provide at least 10% of total plot cover

14. Bush chinquapin provides 40% or greater relative cover within the shrub layer .... **Bush chinquapin – shrub tanoak association**

14' Bush chinquapin provides <10% relative cover within the shrub layer

15. Pinemat manzanita provides 50% or greater relative cover within the shrub layer .... **Shrub tanoak / pinemat manzanita type**

15' Pinemat manzanita provides <5% relative cover within the shrub layer .... **Shrub tanoak / bracken fern association**

1. Shrub tanoak and bush chinquapin are absent; or, if they are present, the plot is riparian

16. The plot is upland

17. Tree tanoak or Douglas-fir composes an important part of the tree canopy (>30% relative cover)

18. Tree tanoak provides at least twice as much cover within the tree canopy as Douglas-fir

19. Ponderosa pine is present and provides as much cover in the tree canopy as tree tanoak .... **Ponderosa pine - tanoak / iris association**

19' Ponderosa pine is absent or provides less than half as much cover in the tree canopy as tree tanoak

20. Mountain dogwood is present .... **Tanoak – mountain dogwood / poison-oak association**

20' Mountain dogwood is absent .... **Tanoak / poison-oak type**

18' Tree tanoak provides much less cover within the tree canopy than Douglas-fir

21. Bigleaf maple is present .... **Douglas-fir – canyon live oak – bigleaf maple / poison-oak association**

21' Bigleaf maple is absent .... **Douglas-fir – tanoak / iris association**

17' Tree tanoak or Douglas-fir does not compose an important part of the tree canopy (<10% relative cover)

22. There is a well-developed tree canopy present in which black oak is an important component (>20% relative cover)

23. Poison-oak more abundant in shrub layer than whiteleaf manzanita or toyon

24. Oregon white oak provides >40% relative cover within the tree canopy .... **Oregon white oak – black oak / poison-oak association**

24' Oregon white oak provides <10% relative cover within the tree canopy

25. Canyon live oak provides >65% relative cover within the tree canopy

26. Bigleaf mapleis present .... **Canyon live oak – bigleaf maple / needlegrass type**

26' Bigleaf maple is absent .... **Canyon live oak / styrax association**

25' Canyon live oak provides <40% relative cover within the tree canopy

27. Styrax provides at least 50% relative cover within shrub layer .... **Ghost pine – black oak / styrax – poison-oak association**

27' Styrax provides <25% relative cover within shrub layer

28. Black oak provides 65% or greater relative cover within the tree layer

29. Poison-oak provides at least twice as much cover within the shrub layer as whiteleaf manzanita .... **Black oak / poison-oak association**

29' Whiteleaf manzanita provides at least twice as much cover within the shrub layer as poison-oak .... **Black oak / whiteleaf manzanita association**

28' Black oak provides <50% relative cover within the tree layer

30. Ponderosa pine provides 15% or greater relative cover within the tree layer

31. Tree tanoak is present .... **Ponderosa pine – tanoak – canyon live oak / poison-oak type**

31’ Tree tanoak is absent .... **Ponderosa pine – canyon live oak / whiteleaf manzanita association**

30’ Ponderosa pine provides <5% relative cover within the tree layer .... **Canyon live oak – black oak / poison-oak association**

23’ Whiteleaf manzanita and/or toyon more abundant in shrub layer than poison-oak

31. Black oak provides 50-75% relative cover in tree layer

32. Canyon live oak provides <20% relative cover in tree layer .... **Black oak / toyon – poison-oak association**

32’ Canyon live oak provides 40-50% relative cover in tree layer .... **Black oak – canyon live oak / toyon – poison-oak association**

31’ Black oak provides <50% relative cover in tree layer

33. A single conifer species provides 10% or greater relative cover in tree layer

34. Ponderosa pine provides 10% or greater relative cover .... **Ponderosa pine – black oak / whiteleaf manzanita – poison-oak type**

34’ A conifer species other than ponderosa pine provides 10% or greater relative cover

35. Knobcone pine provides 10% or greater relative cover .... **Knobcone pine – mixed oak / whiteleaf manzanita**

35’ Ghost pine provides 10% or greater relative cover

36. Shrub white oak provides >25% of total plot cover .... **Brewer oak – birchleaf mountain-mahogany association**

36’ Shrub white oak provides little or no cover (<1 %) on plot .... **Ghost pine – canyon live oak / whiteleaf manzanita association**

33’ A single conifer species provides 5% or less relative cover in the tree layer, or a combination of conifer species provides 10% or greater relative cover .... **Canyon live oak / whiteleaf manzanita association**

22’ There is not a well-developed tree canopy present; or, if canopy is present, black oak is not an important component (<5% relative cover)

34. A distinct tree canopy is present (trees are >4 m in height and their canopy covers at least 30% of plot)

35. Canyon live oak provides >75% total plot cover .... **Canyon live oak / poison-oak association**

35’ Canyon live oak provides <30% total plot cover

36. Interior live oak is the most abundant tree in the canopy (>75% relative cover)

37. Whiteleaf manzanita provides >50% relative cover in the shrub layer .... **Interior live oak / whiteleaf manzanita association**

37' Whiteleaf manzanita provides <5% relative cover in the shrub layer

38. Yellow starthistle provides >20% total cover on the plot .... **Interior live oak / poison-oak / yellow starthistle association**

38' Yellow starthistle provides <5% total cover on the plot .... **Interior live oak / poison-oak association**

36' Blue oak is the most abundant tree in the canopy (>60% relative cover) .... **Blue oak / redbud type**

34' No distinct tree canopy is present

39. Lemmon's ceanothus provides >20% total cover on the plot .... **Knobcone pine / Lemmon's ceanothus association**

39' Lemmon's ceanothus provides <3% total cover on the plot

40. Chamise provides 25-75% relative cover in shrub layer .... **Whiteleaf manzanita / chamise association**

40' Chamise provides <10% relative cover in shrub layer .... **Whiteleaf manzanita – toyon – poison-oak type**

16' The plot is riparian

41. Sierra-laurel is present .... **White alder – sierra-laurel association**

41' Sierra-laurel is absent

42. Tree tanoak provides 50% or greater relative cover within the tree layer .... **Douglas-fir – tanoak / spikenard association**

42' Tree tanoak provides <10% relative cover within the tree layer

43. Incense-cedar provides >10% relative cover within the tree layer .... **White alder / bracken fern association**

43' Incense-cedar provides <5% relative cover within the tree layer

44. A sedge provides >50% relative cover within the herbaceous layer .... **White alder / torrent sedge association**

44' Sedges provide relative cover similar to or less than other herbs .... **White alder association**

Appendix E. Explanation of plant association abbreviations found in Tables 5-25.

Acronym	Definition
Abicon – Pinlam – Pinpon / Lideec	*Abies concolor – Pinus lambertiana – Pinus ponderosa / Lithocarpus densiflorus* var. *echinoides*
Alnrho / Carnud	*Alnus rhombifolia / Carex nudata*
Alnrho	*Alnus rhombifolia*
Alnrho / Leudav	*Alnus rhombifolia / Leucothoe davisiae*
Anrho / Pteaqu	*Alnus rhombifolia / Pteridium aquilinum*
Arcpat – Chrsem / Arcnev	*Arctostaphylos patula – Chrysolepis sempervirens / Arctostaphylos nevadensis*
Arcvis – Hetarb – Toxdiv	*Arctostaphylos viscida – Heteromeles arbutifolia – Toxicodendron diversilobum*
Arcvis – Adefas	*Arctostaphylos viscida – Adenostoma fasciculatum*
Chrsem – Lideec	*Chrysolepis sempervirens – Lithocarpus densiflorus* var. *echnoides*
Lidede / Toxdiv	*Lithocarpus densiflorus* var. *densiflorus / Toxicodendron diversilobum*
Lidede – Cornut / Toxdiv	*Lithocarpus densiflorus* var. *densiflorus – Cornus nuttallii / Toxicodendron diversilobum*
Lideec / Pteaqu	*Lithocarpus densiflorus* var. *echinoides / Pteridium aquilinum*
Lideec / Arcnev	*Lithocarpus densiflorus* var. *echinoides / Arctostaphylos nevadensis*
Pinatt – MO / *Arcvis*	*Pinus attenuata* – Mixed oak / *Arctostaphylos viscida*
Pinatt / Cealem	*Pinus attenuata / Ceanothus lemmonii*
Pinpon – Lidede – Quechr / Toxdiv	*Pinus ponderosa – Lithocarpus densiflorus* var. *densiflorus – Quercus chrysolepis / Toxicodendron diversilobum*
Pinpon – Quechr / Arcvis	*Pinus ponderosa – Quercus chrysolepis / Arctostaphylos viscida*
Pinpon – Lidede	*Pinus ponderosa – Lithocarpus densiflorus* var. *densiflorus*
Pinpon - Abicon / Arcpat – Chrsem	*Pinus ponderosa – Abies concolor / Arctostaphylos patula – Chrysolepis sempervirens*
Pinpon – Pinlam / Lideec	*Pinus ponderosa – Pinus lambertiana / Lithocarpus densiflorus* var. *echinoides*
Pinpon - Pinlam / Arcpat – Lideec	*Pinus ponderosa – Pinus lambertiana / Arctostaphylos patula – Lithocarpus densiflorus* var. *echinoides*
Pinpon / Lideec	*Pinus ponderosa / Lithocarpus densiflorus* var. *echinoides*
Pinpon – Abicon / Lideec	*Pinus ponderosa – Abies concolor / Lithocarpus densiflorus* var. *echinoides*
Pinpon – Pinlam / Lideec	*Pinus ponderosa – Pinus lambertiana / Lithocarpus densiflorus* var. *echinoides*
Pinpon – Quekel / Arcvis – Toxdiv	*Pinus ponderosa – Quercus kelloggii / Arctostaphylos viscida – Toxicodendron diversilobum*
Pinsab – Quekel / Arcvis	*Pinus sabiniana – Quercus chrysolepis / Arctostaphylos viscida*

Psemen – Lidede	*Pseudotsuga menziesii – Lithocarpus densiflorus* var. *densiflorus*
Psemen – Lidede / Aracal	*Pseudotsuga menziesii – Lithocarpus densiflorus* var. *densiflorus / Aralia californica*
Psemen – Quechr – Acemac / Toxdiv	*Pseudotsuga menziesii – Quercus chrysolepis – Acer macrophyllum / Toxicodendron diversilobum*
Queber – Arcpat	*Quercus berberidifolia – Arctostaphylos patula*
Quechr – Quekel / Toxdiv	*Quercus chrysolepis – Quercus kelloggii / Toxicodendron diversilobum*
Quechr / Styoff	*Quercus chrysolepis / Styrax officinalis*
Quechr / Arcvis	*Quercus chrysolepis / Arctostaphylos viscida*
Quechr / Arcpat	*Quercus chrysolepis / Arctostaphylos patula*
Quechr / Lideec	*Quercus chrysolepis / Lithocarpus densiflorus* var. *echinoides*
Quechr / Toxdiv	*Quercus chrysolepis / Toxicodendron diversilobum*
Quechr / rock	*Quercus chrysolepis /* rock
Quechr – Acemac / Achocc	*Quercus chrysolepis – Acer macrophyllum / Achnatherum occidentale*
Quegar – Quekel / Toxdiv	*Quercus garryana* var. *garryana – Quercus kelloggii / Toxicodendron diversilobum*
Quegabr – Cerbet	*Quercus garryana* var. *breweri – Cercocarpus betuloides*
Quekel – Quechr / Hetarb – Toxdiv	*Quercus kelloggii – Quercus chrysolepis / Heteromeles arbutifolia – Toxicodendron diversilobum*
Quekel / Toxdiv	*Quercus kelloggii / Toxicodendron diversilobum*
Quekel / Hetarb – Toxdiv	*Quercus kelloggii / Heteromeles arbutifolia – Toxicodendron diversilobum*
Quekel / Arcvis – Toxdiv	*Quercus kelloggii / Arctostaphylos viscida*
Quekel – Pinsab / Styoff – Toxdiv	*Quercus kelloggii – Pinus sabiniana / Styrax officinalis – Toxicodendron diversilobum*
Quewis / Toxdiv	*Quercus wislizeni / Toxicodendron diversilobum*
Quewis / Toxdiv / Censol	*Quercus wislizeni / Toxicodendron diversilobum / Centaurea solstitialis*
Quewis / Arcvis – Hetarb	*Quercus wislizeni / Arctostaphylos viscida*